Review of Problems in Combined and Partly Combined Sewerage Systems in the Province of Ontario

Research Report No. 93

Research Program for the Abatement of Municipal Pollution under Provisions of the Canada-Ontario Agreement on Great Lakes Water Quality

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These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house projects by both Environment Canada and the Ontario Ministry of the Environment, and contracts with municipalities, research institutions and industrial organizations.

The Scientific Liaison Officer for this project was Mr. D. Hay, Environment Canada.

Enquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

Wastewater Technology Centre
Canada Centre for Inland Waters
Environment Canada
P.O. Box 5050
Burlington, Ontario L7R 4A6

Ontario Ministry of Environment
Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5

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REVIEW OF PROBLEMS WITHIN COMBINED AND PARTLY COMBINED SEWERAGE SYSTEMS IN THE PROVINCE OF ONTARIO

by

Gore and Storrie Limited
Consulting Engineers
Toronto, Ontario

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

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Toronto, Ontario
M4V 1P5

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ABSTRACT

The objective of this project was to identify, assemble, screen and assess background information relating to combined and partly combined sewer systems in Ontario. Case histories of six municipalities were used to emphasize problems and solutions.

A questionnaire was sent to 245 municipalities and a 77 percent response was received. In addition, 33 reports were received and analyzed. The replies and reports, analyzed in seven categories, did not indicate significant correlation and trend. The most prevalent problems indicated by the municipalities were of a quantitative nature. They included: infiltration and inflow, basement flooding, overflows, overloading, bypassing, and area flooding. The effect on receiving water quality of combined sewer overflows did not appear to be a municipal concern.

The geographical distribution, topography, soil conditions and historical background were found to have practically no correlation with combined or partly combined sewer development and their problems. This was also the case with urban population factors, sewer separation programs, economics and other such factors.

RESUME

Cette étude visait à localiser, rassembler, trier et évaluer les données fondamentales ayant trait aux égouts unitaires et pseudo-séparatifs de la province d'Ontario. L'expérience antérieure, acquise par six municipalités, a servi à mettre en relief les problèmes observés et les solutions envisagées.

Des questionnaires, expédiés à 245 municipalités, ont apporté 77 p.100 de résponses. Les auteurs ont également reçu 33 rapports; tous ces renseignements ont été analysés et répartis en sept catégories. Aucune corrélation ne s'est toutefois manifestée et il fut impossible de dégager une tendance significative des réponses obtenues. Les principaux problèmes soulevés étaient d'ordre quantitatif: infiltrations et débits d'entrée, inondations de sous-sols, trop-pleins, surcharges, dérivations et inondations en surface. Les répercussions du trop-plein des égouts unitaires, en ce qui concerne la qualité des eaux réceptrices, n'ont pas semblé préoccuper trop fortement les localités.

On n'a décelé, à toutes fins utiles, aucune correspondance entre, d'une part, l'emplacement géographique, la topographie et les conditions du sol et les problèmes qu'ils suscitent. De plus, il a été impossible de les relier à l'expérience acquise, au coefficient de population urbaine, aux programmes de séparation des égouts, aux facteurs économiques et aux autres éléments similaires.

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SUMMARY

Phase 1 of this project identified, assembled, screened and assessed reports on combined and partly combined sewer systems in Ontario.

Phase 2 emphasized problems in reported "case histories". Solutions and implementation procedures for the solutions for six municipalities were proposed, and government and professional viewpoints on the matter were solicited.

To assess the extent of problems within combined and partly combined sewerage systems in the Province, to determine their geographical distribution and to locate reports dealing with these matters, relevant information was first collected by means of a questionnaire. A 77 percent response was obtained for the questionnaire, which was sent to 245 municipalities (excluding the primarily rural municipalities). These replies, combined with sewer reports of the last 10 years, provided a good working basis. Thirty-three reports, assembled from 26 of the 245 municipalities, were assessed.

An attempt was made to correlate combined sewer problems under the following seven categories:

- geographical correlation,
- topographical correlation,
- soils character,
- history of sewer development,
- economic base,
- urban populations and densities,
- population development factors.

Although all these factors influenced the development of municipal sanitary systems, and particularly the prevalence of combined sewers and their problems, no significant trends could be identified.

Of the 188 municipalities that completed the questionnaire, 69 indicated that combined sewers formed part or all of their sanitary system network. The responses to suggested typical problems were as follows:

Problems	188 Municipalities Overall Response	69 Municipalities with Combined Sewers		
	Affirmative Replies (%)	Affirmative Replies (%)	Negative Replies (%)	Question Not Answered (%)
Infiltration and Inflow	57	83	12	5
Basement Flooding	48	72	22	6
Overflows	40	71	16	13
Interconnections	26	61	28	11
Overloading	38	57	29	14
Bypassing	30	55	30	15
Area Flooding	30	41	48	11
Recreational Pollution	17	30	52	18
Erosion	15	22	58	20

Not only are most of the above problems typical of all sanitary sewer systems, whether combined or separate, but municipal officials also appear to be primarily concerned with quantitative rather than qualitative problems. The concern of provincial regulatory agencies with the qualitative problems of pollution and erosion from combined sewer overflows has not received the same emphasis at the municipal level. It may be concluded that this reflects the prime responsibilities, i.e., municipal responsibility for reliable sewer services, provincial responsibility for health protection and pollution control.

Most of the sewer reports perused and abstracted under Phase 1 of the study dealt primarily with quantitative problems. Often these reports were triggered by hydraulic overloading or flooding conditions or both. They dealt primarily with system enlargements to overcome such problems and to provide for the needs of anticipated future urban growth in the community. Only a few reports contained attempts to analyze the causes of certain dominant problems in more depth.

Other information sources were used to augment the assessment and overview of the problems of combined and partly combined sewerage systems. The following statistics were derived from some of these sources.

1) The total length of sanitary sewers in the province in 1975 appeared to be about 13,800 miles. Of this length, about 3,450 miles or 25 percent consisted of combined sewers. It also appears that about 21 percent of Ontario's population receives sanitary service via combined sewers.

2) By dividing Ontario's total population by the total number of lower tier* municipalities, the overall average population size of the municipalities in Ontario was 9,300, as compared to 4,600 for Canada as a whole. In further comparison, the average for all municipalities in the province serviced by sanitary sewers was a municipal population of 20,000; the non-served municipal average was 3,400**. The average size of municipalities having combined sewers was about 37,400, and about 14,000 for municipalities with separate sanitary systems only.

3) These statistics confirm the finding that older, well-established cities and towns are predominant in having combined or partly combined systems. Most of these were located on the shores of the Great Lakes or on larger rivers and canal systems.

4) In general, very few combined sewers have been built since World War II, and then only as extensions to existing combined systems. Separation of existing systems in a few municipalities has taken the form of either complete separation or partial separation. The latter usually involves the construction of street storm sewers to take surface runoff with roof and foundation drains left connected to the original combined sewers. This practice has, for instance, been adopted by the City of Toronto.

5) Collection of in-depth statistical information on combined sewer problems was complicated by the lack of a clear definition of what constitutes a combined sewer, a partially combined sewer, and a separate sanitary

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* See Municipal Directories. For instance, the City of Toronto is a lower tier municipality and Metropolitan Toronto an upper tier municipality.

** Sixty-five percent of the municipalities in Ontario are predominantly townships with wide-spread population, which cannot be economically serviced.

sewer. Many sewers originally constructed as separate sanitary sewers were modified later on by storm drainage connections or other nonsanitary inflow. Consequently, most identified combined sewer problems are actually typical for all sanitary sewers, whether combined or separate. Generally, therefore, the most prevalent problem noted in the replies to the questionnaire was that of infiltration and inflow, with basement flooding and overflows of next significance. Deterioration of old pipes and joints were of concern.

6) Pollution of recreational areas and erosion were not indicated to be significant concerns in most municipalities.

In Phase 2 of the project, six municipalities were selected for in-depth "case history" study of combined sewer problems and related background information in the seven categories listed. These municipalities were chosen to represent a good provincial cross-section with respect to municipal size, population development, location, topography, and the character of their receiving waters.

The municipalities that were studied were:

	1976 Population (1000's)
City of Toronto	685.3
City of Ottawa	302.1
City of Kingston	61.0
City of Chatham	37.8
City of Thorold	14.7
Town of Campbellford	3.4

The in-depth case studies were made from information obtained in local interviews and from collected sewer reports and other related documents. They showed that geography, topography, historical development, economic base and similar factors all played a role to a considerably varied extent in the development of sanitary sewers, combined systems and their problems in each municipality. The main system conditions and problems, therefore, appeared to be different in each municipality.

If, for each of the six case studies, three main factors relating to combined sewer problems were listed in descending order of importance, they might be summarized as follows:

	First Rank	Second Rank	Third Rank
Toronto (primarily with respect to actual City area)	Historical Growth	Pollution from Overflows	Basement Flooding
Ottawa	Pollution from Overflows	Historical Growth	Sewer Capacities
Kingston	Soil conditions (Rock)	System Capacities	Infiltration
Chatham	Topography	Flooding	Trunks and pumping stations
Thorold	Historical Growth	Sewer Conditions	Pollution
Campbellford	Financial Factors	Pollution	Sewer Capacities

The case studies were an attempt to emphasize information that could provide insight into certain general problems and conditions against a background of information on financial factors, historical growth, etc.

1 INTRODUCTION

1.1 Terms of Reference

The salient points of the study objectives may be listed as follows:

Phase 1 - The task of this initial phase included collection, screening and assessment of reports on combined and partly combined sewers in Ontario prepared within the last 10 years with emphasis on:

1) reports that were comprehensive in nature,
2) municipalities with a significant percentage of sanitary sewerage flow directed to combined sewers,
3) problems encountered and their geographical distribution,
4) classification of these problems.

Information relating to regulatory practices was also to be collected.

Phase 2 - This second phase involved two separate tasks as follows:

Task 1 - Summarizing "case history" problems, their solutions and implementation. These were to be reviewed in context with relevant regulatory and fiscal constraints and municipal "follow up" action on report recommendations.

Task 2 - Soliciting formally the collected viewpoints of:

a) relevant professional associations,
b) relevant federal and provincial agencies.

1.2 Background

In 1972, under the Canada-Ontario Agreement (COA) on Great Lakes Water Quality, an Urban Drainage Sub-committee (UDS) was established as part of the research program for abatement of municipal pollution. The UDS was formed to deal with the need to control pollution caused by overflows from combined sewerage systems and urban surface runoff. The UDS undertook to develop a program which would define the problems, develop a means of solving them, and develop a strategy for implementing the solutions. The specific terms of reference were to:

1) establish studies to define the magnitude of the pollution problems due to urban runoff;
2) establish studies directed toward potential solutions to urban runoff problems; and
3) develop a strategy for implementing solutions.

This study is one in a series of over 50 research and development projects initiated by the UDS.

1.3 Task Definition for Phase 1

Although the scope of the UDS objectives refers to the Great Lakes Basin, there are only a few Ontario communities outside the Great Lakes watershed of the size canvassed under this study. These have, therefore, been included to make the study comprehensive for Ontario. Where a regional or similar upper-tier level of government exists it was considered a separate municipality.

Of some 832 municipalities in Ontario, townships of less than 5,000 population and towns of less than 2,500 population were not considered to be of significant size to be included in the study. Their exclusion left 245 municipalities.

At the start of the assignment, it was agreed that the principal method of initial information collection would be a questionnaire forwarded to these 245 municipalities in Ontario. The questionnaire is shown in Appendix A.

The terms of reference required an analysis of types of problems. The most obvious problem to be expected might be flooding of basements and streets due to inadequate capacity for increased runoff from expansion in developed or re-developed areas. Other problems could be blockage due to structural failure, penetration by roots, deposition of solids and creation of septic conditions due to flat grades and low velocities, etc. Overflows and bypasses could occur and create pollution of watercourses and receiving waters. A classification of anticipated problems is shown in Appendix B.

Whether or not geographical location was related to certain types of problems was to be determined. For example, frost penetration would be more critical in parts of northern Ontario.

Also to be determined was whether problems and causes were sufficiently recurring to be classified and whether a rational basis for the various classifications could be found.

1.4 Identification of Combined and Partly Combined Sewer Systems

The identification of combined and partly combined sewer systems is complicated by differences of opinion on what constitutes a true combined sewer and, even more so, by what sewers should be considered partly combined.

As discussed in more detail in Appendix B, certain definitions are provided in the 1969 "Glossary - Water and Wastewater Control Engineering" of the WPCF, AWWA, ASCE and APHA, but neither "combined sewer" nor "partly combined sewer" are defined. As at least "combined wastewater" is defined in the glossary, Appendix B suggests, in addition, one definition for "a partly combined sewer system" and one for "a partly combined sewer".

Furthermore, it is recognized that separate sanitary sewers may carry "minor" quantities of ground, storm and surface wastes that are not admitted intentionally. Interconnections constructed to provide relief have, in cases, "perverted" separate systems.

For the purpose of this report, a "combined sewer system" is one intentionally designed to receive both wastewater and storm water. A "partly combined sewer system" is one collecting wastewater and storm water from an area where some, but not all, storm water runoff is collected in a system of separate storm sewers.

Table B.1 in Appendix B attempts to describe and quantify sanitary and storm flow contributions for combined sewers, partly combined sewers, interconnected and separate storm and sanitary sewers, but it is recognized that with the many possible variations, a clear distinction in many cases is difficult to make.

2 PROBLEM CLASSIFICATION

2.1 General

As a part of the study, the types of combined sewer systems problems encountered were to be categorized and some categories were suggested for consideration. These have been expanded and are discussed in the following pages under:

- Geography
- Topography
- Soils character
- History of sewer development
- Economic base
- Urban population and densities
- Population development factors

Classification of the problems under these categories has been most difficult and without significant results.

2.2 Municipalities with Combined and Partly Combined Sewer Systems

A listing was made of the municipalities with combined sewers from the results of a questionnaire survey. Table 1 lists municipalities with combined sewer systems by 1976 population. Where the information was readily available the table lists the outlet geography, the general topography of the relevant municipalities, and their general soils characteristics for convenient comparison and correlation of these three factors. Since it appears that most of the more extensive combined sewer systems were constructed before World War II, the 1936 populations are also shown.

2.3 Geographical Considerations

Most of the cities and towns with combined sewers are located along the Great Lakes shores and along larger rivers or canal systems which provided a transportation link to the Lakes. These lakes and rivers also provided a means of disposal of wastewaters without treatment.

TABLE 1. COMBINED SEWER SYSTEM IDENTIFICATION

SURVEY NO.	REFERENCE NO.	MUNICIPALITY (Underlined Reports Received)	ASSESSED POPULATION 1976	ASSESSED POPULATION 1936	OUTLET GEOGRAPHY	TOPOGRAPHY	SOILS CHARACTER
A. LARGER THAN 100,000 POPULATION (of Total of 16 Municipalities)							
215	C1-A1	City of Toronto	685,333	645,462	Rivers/Lake Ontario	Lake shore land and gentle hills	Sand, silt, till
190	B2-A2	Borough of Scarborough	372,278	21,834	Creeks/Lake Ontario	Gentle hills	
87	C2-A3	City of Hamilton	311,886	154,020	Bay/Lake Ontario	Niagara Escarpment; flat above and below	
153	C3-A4-11	City of Ottawa	302,124	141,903	Ottawa River	Rolling and sloping to gullies and river	Leda clay, glacial tile rock
112	C4-A5	City of London	243,928	73,091	Thames River	Mostly flat	
238	C6-A6	City of Windsor	198,569	101,435	St. Clair River	Mostly flat	
244	B4-A7	Borough of York	140,184	87,503	Creeks/Lake Ontario	Sloping and hilly to creeks	Sand, silt, till
107	C7-A8	City of Kitchener	130,228	32,650	Grand River	Mostly flat	
209	C9-A9	City of Thunder Bay	108,571	44,276	Lake Superior/River	Sloping to Lake	
55	B5-A10-22 -11	Borough of East York	104,677	39,759	Creeks/Lake Ontario	Mostly flat	Sand, silt, till
B. 20,000 to 100,000 POPULATION (of Total of 39 Municipalities)							
21	C12-B1	City of Brampton	98,590	5,568	Creeks	Rolling, sloping to creeks and to south	Till and clay
103	C19-B2	City of Kingston	61,003	23,513	Lake Ontario	Hilly, sloping to creeks, rivers and lake	Varaible and rock
187	C21-B3-22	City of Sarnia	55,031	18,230	St. Clair River	Flat core area	south - clay loam north - coarse sand
43	C24-B4	City of Cornwall	45,743	12,681	St. Lawrence River	Rolling	Till and soft clays
35	C27-B5	City of Chatham	37,803	15,910	Thames River	Flat - low lying	Clays, sand, silt
15	C28-B6	City of Belleville	35,089	14,509	Lake Ontario	Partly flat; some hills	Till, clay and some rock
184	C30-B7-22	City of St. Thomas	26,853	16,088	Thames River	On ridge - gentle slopes	Till, clay and some rock
240	C31-B8-22	City of Woodstock	26,137	11,040	Thames River	Mostly flat	Sand and gravels
69	T10-B9	Town of Fort Erie	23,072	5,655	Lake Erie	Hilly	
220	C35-B10	City of Vanier	20,146	6,852	Ottawa River	Hilly	
C. 10,000 to 20,000 POPULATION (of Total of 51 Municipalities)							
155	C38-C1-11 -40	City of Owen Sound	18,730	13,100	Sydenham River	River valleys and hills Low lying areas	Silt and rock
208	C40-C2	City of Thorold	14,694	4,959	Welland Canal	Mostly flat; some rolling hills	Clay and till; some rock
109	T21-C3	Town of Lincoln	14,252	4,287	Lake Ontario		
110	T25-C4	Town of Lindsay	13,066	7,116	Scugog River		
136	T29-C5	Town of Niagara-on-the-Lake	12,383	1,563	River/Lake Ontario	Flat, gentle slopes	
121	T31-C6	Town of Midland	11,331	6,690	Georgian Bay		
108	T34-C7-16	Town of Leamington	11,012	5,340	Lake Erie	Some flat; some steep slopes	
226	T35-C8	Town of Wallaceburg	10,717	4,660	Sydenham River	Flat	Silty clay, fine sand
42	T36-C9	Town of Collingwood	10,587	5,498	Georgian Bay	Fairly flat	
100	T37-C10	Town of Kenora	10,467	7,962	Lake of the Woods		
94	T39-C11	Town of Huntsville	10,149	2,700	Lake		

TABLE 1. (CONT'D)

SURVEY NO.	REFERENCE NO.	MUNICIPALITY (Underlined Reports Received)	ASSESSED POPULATION 1976	ASSESSED POPULATION 1936	OUTLET GEOGRAPHY	TOPOGRAPHY	SOILS CHARACTER
D. 5,000 to 10,000 POPULATION (of Total of 80 Municipalities)							
92	T41-D1	Town of Hawkesbury	9,552	5,922	Ottawa River		
172	T42-D2	Town of Port Hope	9,320	4,564	Lake Ontario		
197	S2-D3	Town of Smiths Falls	9,232	7,623	Rideau River	Rolling	Little cover to rock
70	T43-D4	Town of Fort Frances	9,074	5,509	Rainy River		
19	T48-D5-35	Town of Bracebridge	7,810	2,589	Muskoka River		
76	T50-D6	Town of Goderich	7,284	4,336	Maitland River and Lake		
97	T52-D7	Town of Iroquois Falls	6,728	1,300	Abitibi River		
156	T55-D8	Town of Paris	6,364	4,315	Grand River		
202	T56-D9	Town of Sturgeon Falls	6,263	4,993	Sturgeon River and Lake Nipissing		
66	T58-D10	Town of Fergus	5,920	2,785	Grand River		
61	T59-D11	Town of Espanola	5,744		Spanish River		
162	T61-D12	Town of Perth	5,632	4,184	Rideau River		
157	T63-D13	Town of Parry Sound	5,470	3,395	Georgina Bay		
133	T64-D14	Town of New Liskeard	5,461	2,865	Lake Timiskaming		
161	T65-D15	Town of Penetanguishene	5,408	4,061	Georgain Bay		
63	T66-D16	Town of Essex	5,388	1,798	Creeks		
12	T70-D17	Town of Aylmer	5,030	1,995	Creeks (Lake Erie)		
E. LESS THAN 5,000 POPULATION (of Total of 136 Municipalities from 2,500 to 5,000 Population							
173	S4-E1	Town of Prescott	4,928	2,942	St. Lawrence River		
7	TR69-E2-16	Township of Anderdon	4,812	1,866	Detroit River		
82	T73-E3	Town of Haileybury	4,868	2,622	Lake Timiskaming		
40	T74-E4	Town of Cochrane	4,844	3,404	Creeks (Abitibi River)		
130	T75-E5	Town of Napanee	4,804	3,061	River to Quinte Bay		
105	T78-E6-16	Town of Kingsville	4,565	2,282	Lake Erie	Gentle slopes	
225	T79-E7	Town of Walkerton	4,512	2,350	South (to Lake Huron)		
119	T81-E8	Town of Meaford	4,260	2,719	Georgian Bay		
211	T83-E9-16	Town of Tilbury	4,215	1,992	Creek (Lake St. Clair)		
4	T89-E10	Town of Almonte	3,650	2,300	Mississippi River		
30	T91-E10-04	Town of Campbellford	3,443	2,849	Crowe River		
65	T92-E11	Town of Exeter	3,390	1,629	Ausable River (to Lake Lake Huron		
2	T93-E12	Town of Alexnadria	3,367	1,926	River to St. Lawrence (Lake St. Frances)		
129	C37-E13	City of Nanticoke - Former Village of Port Dover	3,099	1,665	Lake Erie		
73	T99-E14	Town of Geraldton	3,007		Kenogamisis Lake		Pre-Cambrian rock
118	T102-E15	Town of Nattawa	2,728	1,906	Ottawa River		
52	T105-E16	Town of Durham	2,511	1,816	Sougen River		

Figure 1 shows the geographical distribution in the most populated area of Ontario. This distribution indicates no particular correlation to specific geography.

Although many municipalities with populations of less than 20,000 reported that they had combined sewers, it appears from perusal of reports on sewer systems that these were mainly constructed originally as sanitary sewers to which storm drain connections were made at a later stage, often to the extent that they now are effectively combined sewers. In Appendix B reference is made to such systems as "perverted" separate systems.

In Table 2 a more detailed sewer system and problem overview is given geographically, by distribution in the designated regions of the Ontario Ministry of the Environment. No apparent pattern evolved from such listing.

Table 3 shows the distribution of the municipalities reporting combined sewers with respect to rivers and lakes. From this tabulation it is evident that Lake Ontario is the main receiving water for combined sewer systems.

2.4 Topographical Considerations

An examination of the general topography of the municipalities reporting combined sewer systems shows a wide range of features from relatively flat land to predominantly hilly with various slopes.

It might be assumed that municipalities desiring sanitary sewer services because of growth and surface drainage problems due to the topographical features of the area could accommodate both with a single sewer. Both of these factors were required but were not the major deciding influences for proceeding with combined sewer construction.

The incidence of combined sewers in predominantly flat terrain is slightly higher than in predominantly hilly. The information, abstracted from the reports received (for municipalities indicated in Table 2) was, however, too general to quantify information of this nature.

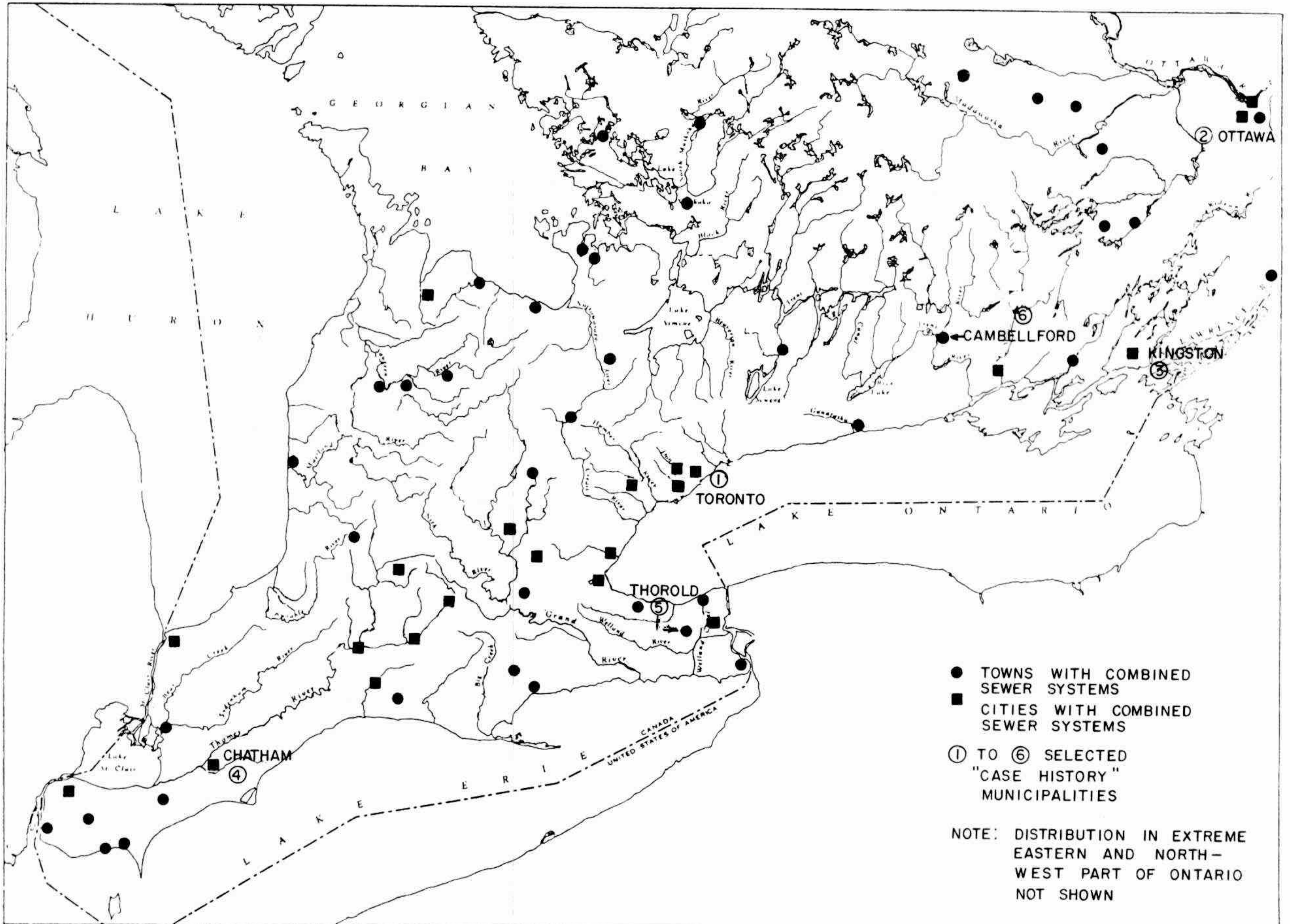

FIGURE 1. GEOGRAPHICAL DISTRIBUTION OF MUNICIPALITIES REPORTING COMBINED SEWERS AS PART OF THEIR SANITARY SYSTEMS

TABLE 2. SEWER SYSTEMS AND PROBLEMS OVERVIEW GEOGRAPHICALLY BY REGION FOR MAJOR MUNICIPALITIES

Regions and Municipality			Sewer System Description	Report Summary	Hydraulic Overloading P.1.1	Hydraulic Overloading P.1.2 & Flooding	System By-Passing (P2) Over-Flows	System By-Passing (P2) By-Passing	Solids Deposition P.3.1 to P.3.5	Infiltration/Inflow P.4.1 Inf.	Infiltration/Inflow P.4.2 Inflow
1. Southwestern Region											
London	112	6.15	Combined sewers in core	x	Yes	Basement	Yes	Yes		Yes	Yes
Windsor*	238	6.71	No information	-	-	-	-	-	- -	-	-
Sarnia	187	6.80	Combined sewers in core	x	Yes	Basement	Yes	No	Many Flaws	Yes	Major
Owen Sound	155	3.10	Mainly combined sewers	x	Yes	Yes	Yes	Yes	In West End	Yes	Yes
Chatham	35	6.88	Combined sewers in core	x	Yes	Area and Basement	Some	Yes		Limited Problems	
Clinton	38	3.08	No information	-							
St. Thomas	184	5.99	Combined sewers in core	x	Yes	Frequent	Yes	Yes	Many Flaws	Yes	Yes
2. West Central Region											
Hamilton	87	10.27	Combined sewers in core	-	Yes	Area and Basement	Yes	Yes		Yes	Yes
Cambridge	29	2.48	Partly combined sewers	-	Yes	No	No	No		Yes	Yes
Welland	230	2.24	Mainly combined	x	-	-	-	-		-	-
St. Catharines*	182	5.16	Combined and partly combined sewers	x	Yes	Yes	No info.			No info.	
Niagara Falls	135	1.30	All combined sewers	x	Yes	Yes	No info.			No info.	
Kitchener*	107	3.89	Combined sewers in core	-	Yes	Area and Basement	Yes	Yes		Yes	Yes
3. Central Region											
Toronto (Metro)*	215	13.82	Mainly combined sewers	xxx (50%)	Low	Limited Basement	Yes	No	No Info	Yes	Yes
Oakville	145	2.23	NO combined sewers	x	-	-	-	-		-	-
Barrie	13	4.67	NO combined sewers	x	Yes	No	No	No		Yes	Yes
Gravenhurst	79	0.06	No information	-	-	-	-	-		-	-
Peterborough	165	4.51	Partly combined	-	No	Area and Basement	Yes	No		Yes	Yes
Huntsville	94	0.06	Combined	x	Yes	Basement	-	Yes		Yes	Yes
Oshawa	152	2.90	Partly combined	x							
Mississauga	123	3.48	NO combined sewers	x							
4. South Eastern Region											
Kingston*	103	8.63	Combined and partly combined	x	Some	Limited	Yes	Yes	Many Flaws	Yes	Yes
Ottawa	153	11.10	Combined and partly combined	x	No	Area and Basement	Yes	No		Yes	Yes
Cornwall	43	2.93	Mainly combined sewers in core area	x	Yes	Area and Basement	Yes	Yes		Yes	Yes
Belleville	15	5.91	Partly combined	x						Yes	Yes
Perth	162	2.85	Combined sewers in core	-	No	Basement	Yes	No		Yes	Yes
Pembroke	160	5.56	No information	-	-	-	-	-		-	-
Smiths Falls	197	5.55	Combined Sewers	-	Yes	Area and Basement	Yes	No		Yes	Yes
Brockville	25	3.91	Partly combined	x	Yes	Limited Basement	Yes	Yes	Many Flaws	Yes	Yes
5. North Eastern Region											
Sudbury	203	1.50	Partly combined	-	No	No	Yes	Yes		Yes	Yes
Sault Ste. Marie	189	1.46	Partly combined	x	Yes	Area and Basement	Yes	Yes		Very High	High
North Bay	140	0.73	Partly combined	-	Yes	Area and Basement	Yes	Yes		Yes	Yes
Timmins	213	0.08	NO combined sewers	x	Yes	Area and Basement	No	No		Yes	Yes
Parry Sound	157	4.57	Combined sewers	-	No	Basement	Yes	Yes		Yes	Yes
6. North Western Region											
Thunder Bay*	209	1.36	Combined sewers (partly)	x	Heavy	Severe Basement	Yes	Yes		Yes	Yes
Kenora	100	2.76	No information	-	-	-	-	-		-	-

*Additional information on these municipalities is found in COA Research Report No. 81, "Evaluation of the Magnitude and Significance of Pollution Loadings from Urban Runoff in Ontario", American Public Health Association and the University of Florida, 1978.

TABLE 3. GEOGRAPHICAL DISTRIBUTION OF MUNICIPALITIES WITH COMBINED SEWERS WITH RESPECT TO RIVERS AND LAKES

	Percent of Relevant Population	Percent of Relevant Municipalities
Lake Superior	4.0	6.2
Lake Huron	0.4	3.0
Georgian Bay	1.7	9.2
St. Clair River - Detroit River	7.7	4.6
Lake Erie	1.2	6.2
Lake Ontario	52.2	15.4
Inland waters draining to the Great Lakes	19.9	33.9
St. Lawrence River	1.5	3.0
Ottawa River	10.0	6.2
Inland waters draining to rivers	1.4	12.3
Total	100.0	100.0

2.5 Soils Character Considerations

The soils characteristics in the locations of the municipalities under consideration are of wide variety and include clays, silts, sands and gravels, glacial tills and bedrock.

It may be reasoned that municipalities which required both sanitary and storm sewer service, and which were located in areas where the soil characteristics required difficult and expensive construction techniques, would show preference for combined sewer systems. The information available, however, does not indicate such a trend.

In general, and from detailed perusal of the collected information, there appeared to be little or no correlation between the prevalence of combined sewers and prevailing soils characteristics in the locations considered.

2.6 History of Sewer Development Considerations

The reports perused provided little or no information on the development of the combined sewer systems in the relevant locations reported. A list of the reports reviewed is given in Appendix E. The following observations are, therefore, of a general nature:

2.6.1 Sewage treatment

Prior to the late 1930's, municipal sewage treatment was very limited in Ontario. Only the larger cities had been forced to treat their sewage in a central location to protect their potable water sources and public beaches. For this reason, it was not strictly necessary to keep storm and sanitary flows separated since all flows were discharged to the nearest open watercourse.

2.6.2 Combined sewerage

Although it was foreseeable that centralized sewage treatment would eventually become necessary, the money available for sewer construction in the depression years was limited. Most combined sewer systems were constructed at, or prior to, that time and in those municipalities which had grown to the extent that private disposal systems (septic tanks with tile beds, etc.) did not provide adequate health protection.

2.6.3 Combined trunk sewers

A good many municipalities which had sizeable populations in 1936 appear to have combined sewer systems which now can be found in their core areas. Some combined trunk sewers had to be constructed, of necessity, where fast urban growth occurred after the war, because of the need for considerable expansion of the system.

2.6.4 Sewer separation

Extensive separation of existing combined sewer systems has only occurred in the last two decades and is still on-going. Complete separation, in many cases, has become impractical because of the enormous costs. In the City of Toronto, for example, so-called "street sewers" have been constructed which intercept existing street catch basins only, leaving considerable storm flow in the original combined sewers.

2.7 Other Considerations

Appendix D gives additional information on general economic and population factors considered in the study, although no particular correlation with combined sewer problems was found.

3 IDENTIFICATION OF PROBLEMS

3.1 General

In Section 1, it was indicated that 245 municipalities were selected before initial screening by questionnaire. From these 245 municipalities, 188 replies were received, a response of 77 percent, which is considered to be very good. The survey results were analyzed in the following manner:

(a)	General Information	- combined sewers,
		- interconnected sanitary sewers,
		- remedial program,
		- relevant reports commissioned,
		- relevant reports reviewed.
(b)	Sewer Problems	- infiltration and inflow,
		- interconnection,
		- basement flooding,
		- area flooding,
		- overflows,
		- bypassing,
		- recreational pollution,
		- erosion,
		- overloading.
(c)	Regulations for Sewers	- by-laws,
		- planning,
		- subdivision agreements,
		- standards,
		- municipal procedures,
		- fiscal incentives,
		- regulations received,

A summary of the survey results is included in Appendix C. In explanation, it should be noted that an "X" indicates a reply on the questionnaire; where there is a blank with respect to the municipality, the questionnaire was not returned; where there is a dash, the municipality returned the questionnaire but did not answer the questions; and the letters "N.A." mean that the particular question was not applicable to that municipality.

At the end of each of the three tabulations in Appendix C, a summary indicates the total broken down with respect to the type of municipal government.

3.2 Combined Sewer System Problems

In the 188 replies received, 69 municipalities indicated they had combined sewers. These 69 municipalities had a total population of 3,348,000, or 42 percent of the total population of Ontario and 47 percent of the population surveyed.

Of the municipalities indicating that they had combined sewers the incidence of the nine main problems on the questionnaire indicated that a good selection of typical problems was anticipated. The number of responses to the problems is shown in Table 4.

TABLE 4. GENERAL QUESTIONNAIRE RESULTS

Number of Municipalities	Percent	Indicated	Number of Problems
5	7.3	Yes	9
8	11.6	Yes	8
7	10.1	Yes	7
9	13.1	Yes	6
10	14.5	Yes	5
10	14.5	Yes	4
7	10.1	Yes	3
7	10.1	Yes	2
2	2.9	Yes	1
3	4.4	No	To all problems listed
1	1.5	Did not provide any response to the questions	

When the combined sewer municipalities were compared with the separate sewer municipalities, the overall response differed appreciably as shown in Table 5.

The most significant of the problems listed appeared to be infiltration and inflow, for which 83 percent of the combined sewer

TABLE 5. OVERALL RESPONSE TO QUESTIONNAIRE

	"YES" (%)	"NO" (%)	No Answer (%)
A. All Replies			
Combined sewer municipalities	55	33	12
Separate sewer municipalities	21	40	39
B. "Yes" and "No" Replies Only			
Combined sewer municipalities	62	38	-
Separate sewer municipalities	33	67	-

municipalities and 42 percent of the separate sewer municipalities indicated a positive response. The problems in order of significance of number of "YES" replies from municipalities with combined sewers compared to municipalities with separate sewers are shown in Table 6. The responses to combined sewer problems only, and in further detail, are presented in Table 7.

Infiltration and inflow was attributed to such causes as connection of roof and foundation drains, and broken and leaking pipe and joint connections.

Among additional specific problems identified in screening the reports were:

- low drainage areas below the level of the receiving water,
- increased storm runoff due to redevelopment,
- surface improvement and increased population densities,
- deposits in sewers,
- lack of adequate factual data in the local area, with particular reference to rainfall data.

TABLE 6. COMPARISON OF RESPONSES FROM MUNICIPALITIES WITH COMBINED AND SEPARATE SEWERS

Problem	Combined Sewer Municipalities: Number of Replies "YES"	Combined Sewer Municipalities: Percent of 69 combined sewer municipalities	Separate Sewer Municipalities: Number of Replies "YES"	Separate Sewer Municipalities: Percent of 119 separate sewer municipalities
Infiltration and Inflow	57	83	50	42
Basement Flooding	50	72	40	34
Overflows	50	72	26	22
Interconnection	42	61	6	5
Overloading	40	57	31	26
Bypassing	38	55	18	15
Area Flooding	28	41	28	24
Recreational Pollution	21	30	11	9
Erosion	15	22	14	12

TABLE 7. RESPONSES FROM 69 MUNICIPALITIES WITH COMBINED SEWERS

Problem	Number of Replies: "YES"	Number of Replies: "NO"	Number of Replies: Not Answered	In Percent: "YES"	In Percent: "NO"	In Percent: Not Answered
Infiltration and Inflow	57	8	4	83	12	5
Basement Flooding	50	15	4	72	22	6
Overflows	50	11	8	72	16	12
Interconnections	42	19	8	61	28	11
Overloading	40	20	9	57	29	14
Bypassing	38	21	10	55	30	15
Area Flooding	28	33	8	41	48	11
Recreational Pollution	21	36	12	30	52	18
Erosion	15	40	14	22	58	20

3.3 Correlation Between Categories and Combined Sewer System Problems

Analysis of the above specific combined sewer system problems from the viewpoints of geography, topography, soil conditions, urban population factors, reasons for and timing of commencement of sewer separation, regulatory and fiscal constraints, and general economic factors, using the information from the questionnaire responses and reports received, did not yield a clear correlation between any of these categories and the outlined sewer problems.

Except that these categories had some effect on the development of municipal sewer systems locally, as is generally known, there were no significant statistical correlations to indicate definite trends. As confirmed by examination of case histories, outlined hereafter, each municipality appeared to be unique when its combined sewer problems were analyzed in detail.

4 CASE HISTORY PROBLEMS

4.1 Introduction

As outlined in Section 1, one of the two tasks involved the review of "case history" problems. In the discussions with the Steering Committee, it was decided that six municipalities could be adequately studied as selected case histories.

TABLE 8. CASE HISTORY MUNICIPALITIES

Municipality	Assessed Population (1000's) 1976	1936	Receiving Waters	Topography	General Location
Group A - Larger than 100,000					
City of Toronto	685.3	645.3	Lake Ontario	gentle hills, mixture of soils	south-central
City of Ottawa	302.1	141.9	Ottawa River	flat lands	southeast
Group B - Over 20,000					
City of Kingston	61.0	23.5	Lake Ontario	gentle hills and rocky	southeast
City of Chatham	37.8	15.9	Thames River	flat with clay soils	southwest
Group C - Over 10,000					
City of Thorold	14.7	5.0	Welland Canal and Lake Ontario	gentle hills, mixture of soils	south-central
Group D - Less than 10,000					
Town of Campbellford	3.4	2.8	Trent River	flat with clay soils over rock subsurface	south-central

The present relative populations and growth in the past 50 years in these municipalities are depicted in Figure 2.

It was also decided in discussions of the case history investigation that the following information would be of prime interest:

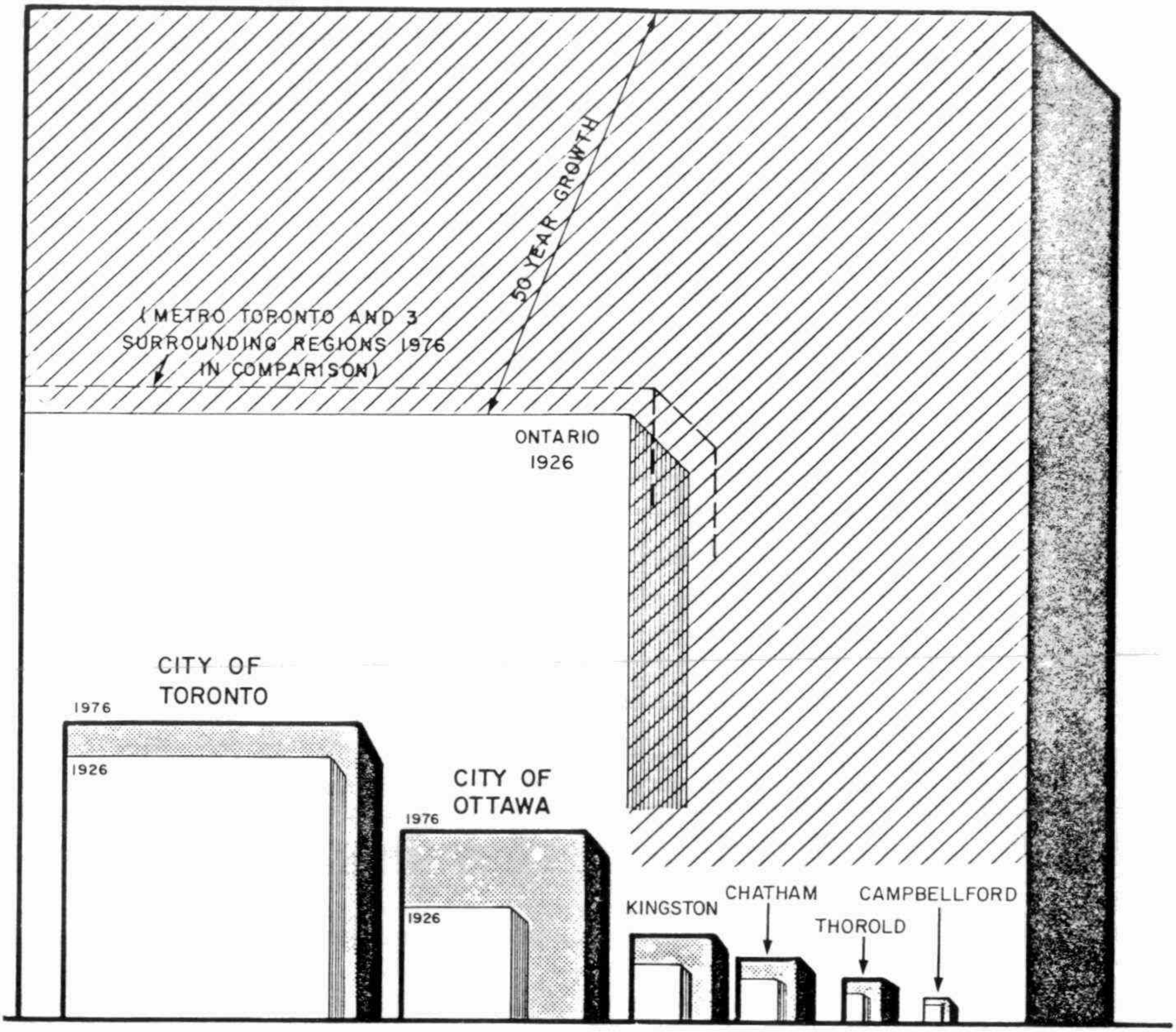

FIGURE 2. PRESENT RELATIVE POPULATIONS AND 50-YEAR GROWTH IN MUNICIPALITIES USED AS CASE HISTORIES

a) General historical information on municipal development, including annexation(s), year of incorporation, population growth, financial development, responsibility for sewer services within the framework of urban development, and related information on development policies and urban growth.
b) Extent of combined sewer systems and individual sanitary and storm sewer systems and number of persons presently served by each system, if possible.
c) The extent and scope of master drainage plans, with accompanying development policies, that have been adopted, especially with regard to particular problems such as flooding and pollution control.
d) Usage, policies or considerations with respect to innovative practices.
e) Detailed statistics on encountered sewer problems, such as the incidence of floodings (basements and surface areas), sewer overloading, sewer maintenance, etc., with costs of remedial works.
f) Information on water quality surveys and history of pollution control, present status and related information.
g) Current programs for remedying sewer problems and improving pollution control, progress of implementation, program financing, including government assistance.

The above information was to be assembled from the following sources:

1) Published statistical information, to afford comparison of the case history data of the six municipalities with Ontario as a whole.
2) Reports and other relevant file information available from the selected municipalities.
3) Interviews to complete the information on the above items a) to g) to the best possible extent within the available study time.

The detailed results of the case history investigation with respect to foregoing information on the six selected municipalities are presented in Appendix F. Only a general discussion of the findings is given in this section.

4.2 Lack of Trends

It again became evident in this in-depth analysis that no specific combined sewer problem correlations or trends seem to exist. Although most municipalities had problems in common within combined or partly combined sewerage systems, each municipality had special conditions and features of sewer development, with ensuing problems, that tended to make it unique. The six case histories showed a wide variety of development and conditions without a particular pattern attributable to size, geography, topography, soils character, history, economic basis, population density or other factors of this nature.

4.3 Comparison of Development in General

The basic development information on population growth and financial information relative to sanitation expenditures, including anticipated future growth, was mainly derived from published municipal statistics and forecasts.

For clarity, only the most salient information is summarized here, while further statistical details are presented in Appendix F, which presents various tables and graphs developed in the case history analysis.

4.3.1 Population growth

The average annual population growth for the six municipalities, in comparison with the province as a whole, for the 50 years from 1926 to 1976, together with projections to the year 2001, is given in Appendix E. The projections were primarily derived from a report by the Ministry of Treasury, Economics and Intergovernmental Affairs entitled "Ontario's Changing Population", published in 1976.

Because of the incompleteness of data for the earliest years of the 50-year period, and some gaps in the numbers for the last two years, the 35-year period 1936-1971 was selected for comparison to projected average growth rates for the next 25-year period, 1976-2001 (Table 9).

TABLE 9. POPULATION GROWTH IN CASE HISTORIES

	Incorporation Year	Historic Growth 1936-1971 Avg. %/Year	Projected Growth 1976-2001 Avg. %/Year
Group A - Larger than 100,000			
City of Toronto	1793 (as Town of York)	0.15	0.87
City of Ottawa	1847 (as Bytown)	2.02	1.69
Group B - Over 20,000			
City of Kingston	1840 (as a Town)	2.67	0.41
City of Chatham	1841 (as a Village)	2.13	0.79
Group C - Over 10,000			
City of Thorold	1850	2.61	1.20
Group D - Less than 10,000			
Town of Campbellford	1876 (as a Village)	0.58	0.19
Average for Groups A-D		1.67	0.82
Provincial Average		2.26	1.45

The average growth rates in Table 9 do not indicate any particular trend in the population groups. Past population growth is not particularly correlated with overall Ontario growth and neither is it correlated to specific time periods. Both past growth and predicted future growth show a random pattern, possibly dictated more by local conditions and development in given time periods than by any general provincial development conditions.

It should be noted that the actual population numbers, from which the above growth percentages have been calculated, have been affected from time to time by municipal boundary changes. Both the population numbers and the size and character of the sewer networks are generally affected by such changes in size of the municipality. For example, in its early years the City of Toronto went through a number of

boundary changes in a relatively short time. Furthermore, although the population of Toronto has increased relatively little the building density has increased enormously.

4.3.2 Financial development

The economic base comparisons on a per capita basis, discussed in general in Section 2, were examined in detail for the six case history municipalities in comparison with the provincial average.

All actual cost information was converted to a per capita basis as well as a constant dollar basis to eliminate population extent and inflation factors. To amplify possible trends as much as possible, all financial analysis results were also calculated as percentages of change from the average for the time period to allow direct comparison between trends for the following financial factors:

- assessment,
- taxation,
- annual sanitation expenditures,
- capital expenditures for public works*,

and the following interrelationship:

- annual sanitation expenditures as a percentage of taxation.

Figure 3 shows, for the province as a whole, the results of the historical/financial analysis. Figure 4 shows the relative rates for the above four factors over the last five years. The graph for municipal taxation in Figure 3 clearly shows that the expenditures for public works were above average during the depression years, then sharply decreased during the war years, and afterwards increased until about 1967, after which they returned to the average.

Assessment in the first half of the 50-year period followed the same trend, but changed relatively little after the war, with only a small upturn in the years 1970-1972, when re-assessment on a provincially

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* Because of wild fluctuations, partly caused by changes in accounting, these have been deleted from the graphs but have been used statistically in the case history analysis.

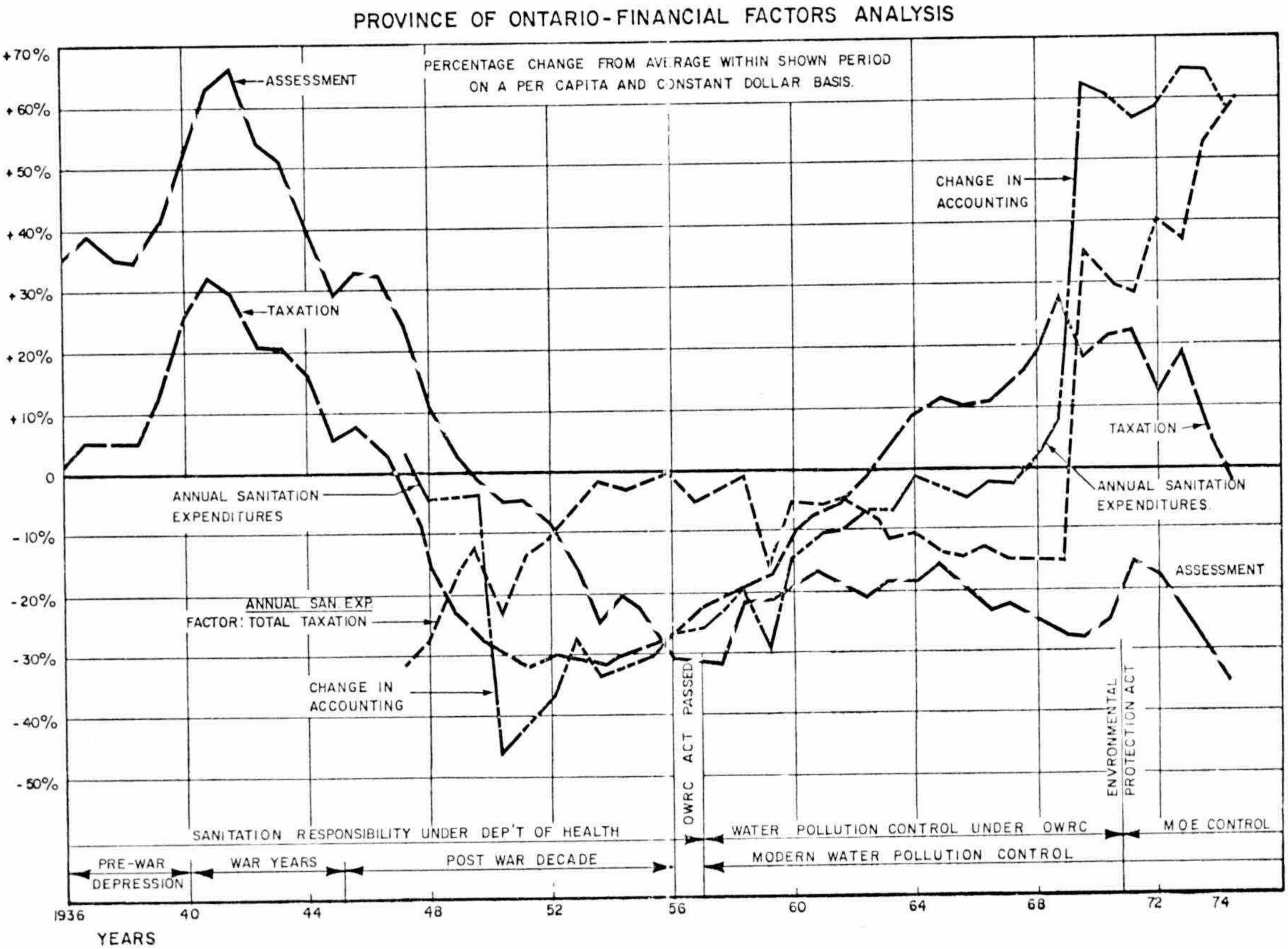

FIGURE 3. ANALYSIS OF FINANCIAL FACTORS

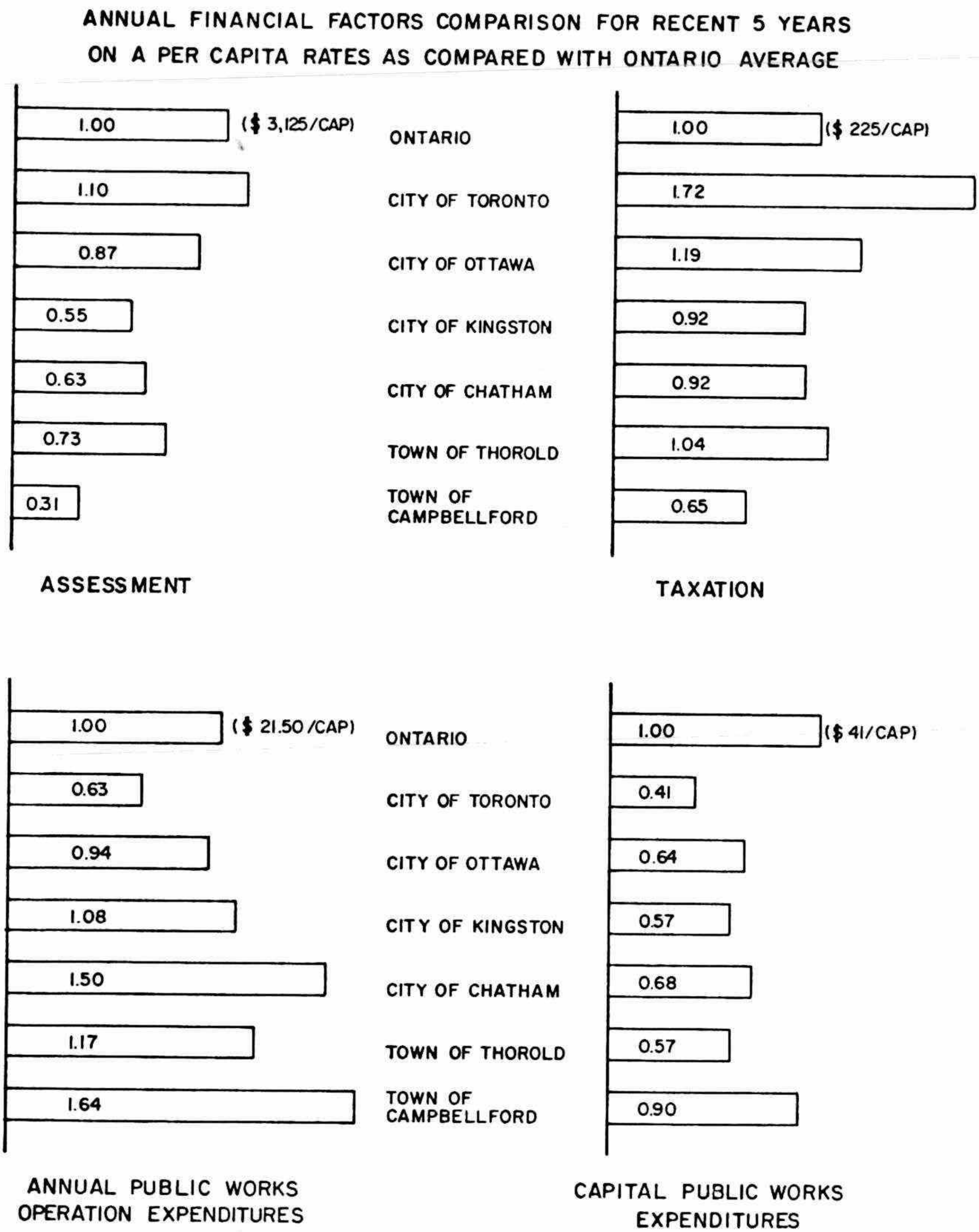

FIGURE 4. COMPARISON OF PER CAPITA RATES FOR FINANCIAL FACTORS FOR FIVE YEARS

equal basis was initiated (assessment became a provincial responsibility in 1970).

Of more interest are the graphs for annual sanitation expenditures. Changes in methods of reporting the annual municipal statistics, as collected and published by the province, caused graphical distortions, but there is still a fair correlation between general taxation and sanitation expenditures.

Between 1940 and 1967 the annual sanitation expenditures, as published (i.e., one single item covering operation and amortization costs for sewerage works as well as certain costs for solid waste disposal) averaged 5.9 percent of overall taxation (minimum 4.5 percent to maximum 6.8 percent). With the change in statistics reporting in 1968 this average percentage rose to 9.25 percent. These changes are shown in Figure 3.

4.3.3 Historical comparison

Figure 5 shows the development of Upper Canada, now mainly the southern part of the Province of Ontario, in about 1841. Thorold and Campbellford were at that time small settlements and are not shown on the map. Ottawa is identified as "Bytown" and consisted mainly of a military camp. At that time Toronto, as one of the older municipalities, may have had some sewers which were of the combined type and essentially wooden box culverts, but by and large most settlements had outside facilities or similar individual home sanitary facilities.

With formal incorporation, municipal works usually became organized and most true municipal sewer construction may be assumed to have formally started at some time after the year of municipal incorporation. However, even for the City of Toronto, the historical information in this respect is fairly limited and the first official records of formal sewer construction for that city were found in the 1891 Annual Report of the City Engineer.

In most cases (as is still often the case) development of a municipal water supply often went hand-in-hand with sanitary sewer construction and also road paving work went hand-in-hand with storm drainage construction.

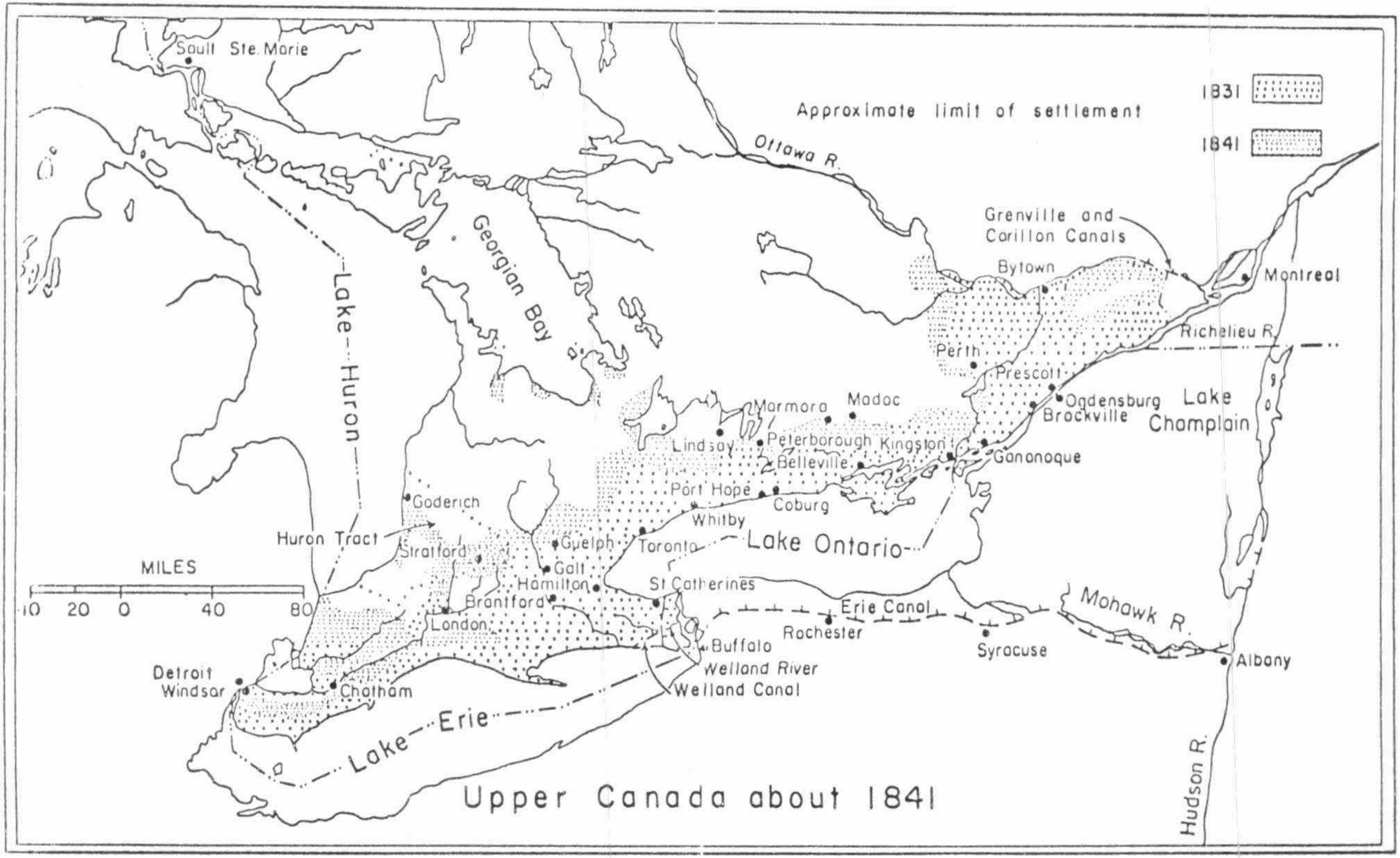

FIGURE 5. UPPER CANADA ABOUT 1841

Municipal growth, and with it municipal sewer system growth, has varied considerably in the past with a number of factors, which employment opportunities appear to have governed. The age of the municipality is considerably less relevant. Thorold and Chatham were incorporated at about the same time as Ottawa, but are now much smaller.

The evolvement of combined sewers and the extent of their construction appears to vary considerably as well, with little correlation to historical municipal development.

Toronto and Thorold, which are both located in relatively flat areas, show a very different pattern of combined sewer development. In Toronto combined sewers were constructed from the outset and, apart from partial separation in more recent years, most older sewers in this city are combined. Thorold's first sewers were built as sanitary sewers which later became semi-combined by the connection of catch basins. In the second stage of Thorold's development, combined sewers were purposely constructed but afterwards only separate systems were built although sewage treatment did not exist at that time.

4.4 Extent of Sewer Systems

The present extent of separate sanitary sewers and combined sewers in the six municipalities is shown in Table 10. Separate storm sewer systems have not been included.

On the average, it appears that about 44 percent of the total length of sewers is separate and 56 percent is combined in these municipalities.

The approximate per capita length of sewer was also calculated for Ontario, using information obtained during preparation of the case histories, and data from other municipalities. From these statistics, the variation in length of sanitary systems (i.e., sanitary plus combined sewers) ranged from 5.65 linear feet per capita for the largest municipality (Toronto) to about 34 linear feet per capita in the smallest listed municipality (Iroquois).

4.5 Adequacy of Sewer Systems

Considering maximum flow design, one would theoretically expect the average diameter of storm sewer systems to be in the order of 5 to 10 times that of sanitary sewer systems, when serving the same

TABLE 10. TYPE AND EXTENT OF SANITARY SEWER SYSTEMS FOR CASE HISTORIES*

	Separate Sanitary Sewers (miles)	Combined Sewers (miles)	Total Length (miles)
City of Toronto	114.3 or 15.7%	614.4 or 84.3%	728.7 or 100%
City of Ottawa	383.61 or 67.1%	188.17 or 32.9%	571.78 or 100%
City of Kingston	74.64 or 66.2%	38.11 or 33.8%	112.75 or 100%
City of Chatham	55.64 or 61.0%	35.64 or 39.0%	91.28 or 100%
City of Thorold	11.38 or 44.0%	14.47 or 56.0%	25.85 or 19.0%
Town of Campbellford	1.9 or 10.0%	17.1 or 90.0%	19.0 or 100%
Average percent	$\pm$44%	$\pm$56%	100%

* Storm sewers not included.

overall area. The few cases of complete sewer inventories by length and size, however, indicated an actual ratio considerably lower, possibly more in the range of 1 to 3 times rather than 5 to 10 times the average sanitary pipe diameter. For instance, for the Chatham system the average sanitary sewer diameter was 13.61 inches and the average storm sewer diameter was 23.99 inches, for a ratio of 1 to 1.76. In comparison, the average diameter of the combined sewers in Chatham was 12.83 inches, thus even smaller than that of the separate sanitary sewer system.

In Brockville and Iroquois, which both have complete separate systems, the ratio of average sanitary to storm pipe diameter was, respectively, about 1 to 1 and 1 to 2. Nevertheless, flooding problems were found to be rather infrequent. In the case of Brockville, this is because of relatively steep sloping streets; and in the case of Iroquois because

of the prevalence of ditches. From the collected information and observations over many years, it appears that, in general, sanitary sewer systems tend to be adequate as long as inflow/infiltration rates are reasonably low. However, storm sewer systems, as well as combined systems, are often inadequate when one considers fair-sized drainage areas and larger systems as a whole. Combined sewer system separation is often an excellent way to overcome, at least partially, such inadequacies.

4.6 Master Drainage Plans

Although some advanced planning is always necessary for public works projects, including sewerage works, and most municipalities now have five-year budget plans which are updated with the detailed annual budgeting at the beginning of each year, the number of municipalities which have complete master drainage plans for longer planning periods is still very limited. This can be readily understood because such master drainage plans must generally be developed on the basis of an adopted official plan, and the development of official plans, a relatively modern municipal task, in turn requires extensive planning studies. These studies and the actual development, planning discussion, adoption and amendments take considerable time, as is demonstrated in the information collected for the six case histories.

a) City of Toronto

Certain planning studies prior to the formation of Metropolitan Toronto in 1954, its reformation in 1967 and since then have taken time, so that an official plan for the City of Toronto in its present form was not adopted until 1976. The Commissioner of Works' 1965 and 1970 sewer system reports contain extensive proposals for future sewer development, but cannot be considered "master drainage plans". Thus, the city has not as yet a true master drainage plan.

b) City of Ottawa

Regionalization followed that of the Toronto area 15 years later in 1969 but, because of the urgent needs, especially with widespread basement flooding in 1969 and 1971, a study for a sewer policy report and long-term master plan was commissioned in the city in 1971 and completed in 1973, independent of the completion of official planning.

c) City of Kingston

Following planning studies started in 1960, Kingston's first official plan was adopted in 1970 and, after certain amendments, replaced with the 1976 official plan. The city has no long-term overall master drainage plan and no particular need for such plan is considered because the city is practically fully-developed within its present boundaries, at least with respect to housing.

d) City of Chatham

Adoption of Chatham's first official plan took place in 1961 and a review in 1975 provided a master development plan for the next 40 years. There is, however, within the present city boundaries, only space for five more years of development. A report and master plan for the city's storm sewer system was completed in 1976, based on planned development beyond the present city boundaries.

e) City of Thorold

Planning activities begun before and continued after the incorporation in 1970 of the Niagara municipalities, including Thorold, in the Region of Niagara, are still on-going. In 1970 a start was made on the official plan for the present City of Thorold, which now includes the former Township of Thorold, but its completion is subject to regional official planning being finalized. No master drainage plan exists or is considered at this stage.

f) Town of Campbellford

An official plan was adopted in 1973 but no master drainage plan exists or is considered necessary with the very limited growth of this community (present unemployment being 30 percent of the working population).

g) General

In the above six municipalities and most others in Ontario, past sewer planning has addressed itself to the most urgent needs, generally because of flooding and pollution control problems. Consultants' studies and recommendations to overcome these problems formed the backbone of sewerage system upgrading and planning for longer terms but, by nature, primarily involved planning and construction of relief sewers, trunk sewers, pumping stations and sewage treatment plants.

For new development (subdivisions) and redevelopment, municipalities tended to control rather than be more positively involved in drainage planning and, at present, this is generally still the case.

A prime requirement for good master drainage planning is a comprehensive inventory of the existing sewer systems. Although most larger municipalities have overall plans of their existing systems, many lack accurate complete information on lengths, depths, grades, sizes, existing and required capacities, etc., on all their sewers, and have such detailed information only for their larger or trunk sewers.

4.7 Innovative Practices

The results of a cursory investigation of the extent of innovative practices in the six municipalities may be summarized as follows:

a) On-surface storm water retention to reduce runoff flow peaks in storm and combined sewers: Deliberate increases in retention on streets, sidewalks, rooftops, parking lots, parks or schoolgrounds hardly exist as yet and are being only preliminarily considered by some.
   - In the City of Toronto only one instance of rooftop retention and two instances of on parking lot retention were cited.
   - In Thorold, in one instance, restrictions in catch basin inlets have been used to increase retention in a street; rooftop retention is under consideration; for certain new developments retention in parks, parking lots, etc. may be adopted.
   - In Chatham it is planned, in a new development area, to provide relatively large retention areas, mainly in parks.

b) Pressurized and vacuum type sewer systems: Only the City of Toronto has made some study of these systems for consideration of application at Toronto Island.

c) Mathematical modelling of storm water runoff and pollution for combined and storm sewer systems: This innovative

practice appears to be primarily interesting to large municipalities with involved systems and conditions. These include Toronto and Ottawa, which have been in the forefront in this respect.

d) Continuous recording and/or control of sewer overflows, particularly from combined sewers with regard to flow quantities and/or strength: None of the six municipalities own and operate such devices. One municipality stated that: "if it rains, we overflow, but we do not measure nor control for how long, how much and at what sewage strength". Assessment of quantities on a theoretical/mathematical basis, of course, can be and is made but there is little factual information to back this up, other than from some government-sponsored field studies.

e) Inflow/infiltration control and rectification: This is primarily of interest for separate sanitary sewers and partly combined systems, but all six municipalities are active on these problems. One innovative practice, initiated in the City of Toronto, is to line smaller sewers by inserting a smaller diameter plastic pipe. Although technically successful, the relatively high costs have prevented this innovation from becoming wide-spread. Of the other five municipalities, only Thorold has 2500 linear feet of trunk sewer lined in this manner.

All municipalities, even the relatively small Town of Campbellford, carry out programs of investigation, mainly by means of camera inspections and smoke testing. Investigations with respect to quantities of inflow and infiltration are still relatively limited, mainly because of their relatively high costs and because their complexity makes true source identification difficult. Rectification work has become a regular budget item, but is pragmatic in nature, i.e., primarily the largest sources and system flaws

are tackled first, where rectification at relatively low cost can be accomplished.

f) Combined sewer overflow regulators: In all six municipalities there are, nearly exclusively, static devices such as weirs and orifices. Dynamic regulators are as yet rare.

g) Use of drag-reducing additives: This is yet an unknown practice. None of the persons interviewed in any of the six municipalities was even aware of their existence and application potentials.

h) Sewer cleaning methods: No innovative practices became evident in the interviews. As to equipment, both conventional mechanical and hydraulic cleaning methods are in use, with some of the six using mainly their mechanical equipment, and others preferring primarily hydraulic cleaning with their own forces or by specializing firms.

   With respect to sewer cleaning scheduling and programs, the pragmatic approach of primary need appears most prevalent. Sewers in good condition which give no trouble are simply never cleaned. Very troublesome sewers may be cleaned more than once a year. Statistical comparison between the six municipalities, therefore, was not considered meaningful and not attempted.

i) Treatment of storm runoff and overflows; usage of storm water holding tanks or ponds: None of the six municipalities practices this or has considered it to any appreciable extent. Toronto has an old storm tank in High Park which will be scrapped soon. Kingston considered a storm tank for its northwest drainage area but selected another solution to the problem.

4.8 Receiving Water Pollution Information

None of the six municipalities regularly received or systematically collected information on pollution of its receiving waters*. They all were found to rely primarily on control and guidance by the provincial authorities and their designated engineering staff, i.e., primarily the Health Inspection Authorities before 1957, and mainly the Ontario Water Resources Commission (OWRC) and Ministry of Environment after the passing of the 1957 Ontario Water Resources Act. From time to time, local investigations of receiving water quality with respect to bacterium count are carried out by health officials, and the Federal Government has certain involvement, especially through the Fisheries Act, but provincial control is most extensive.

The OWRC published its first annual water quality data report from its river basins surveys in 1964-1965, but it appears that many or perhaps most municipal sanitation engineers never receive these publications.

With respect to the six municipalities studied, the only engineering report information of significance on the pollution conditions of receiving waters was found in the City of Toronto's 1970 report. It contains tabulations of coliform concentrations for the years 1965 to 1969, and the arithmetic annual means of all readings from samples taken by the City Department of Health at 23 test points along the lakeshore and Toronto harbour. It is interesting to note that only 14 percent of the listed numbers were below the indicated limit of pollution of 2000 total coliforms per 100 ml on an overall basis in these five years and 25 percent were below this limit, when all readings obtained within 24 hours of combined overflows were excluded. In the 1970 Toronto report tabulations, the annual variations from year to year for all sampling points are considerable and no consistent trend is obvious.

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* This applies to the municipal works departments. In the larger municipalities the local health authorities, of course, are actively involved in pollution control. Also some major reports such as the "Thames River Basin Water Management Study" and the "Rideau River Pollution Abatement Report" are separate undertakings, establishing conditions at a given point in time.

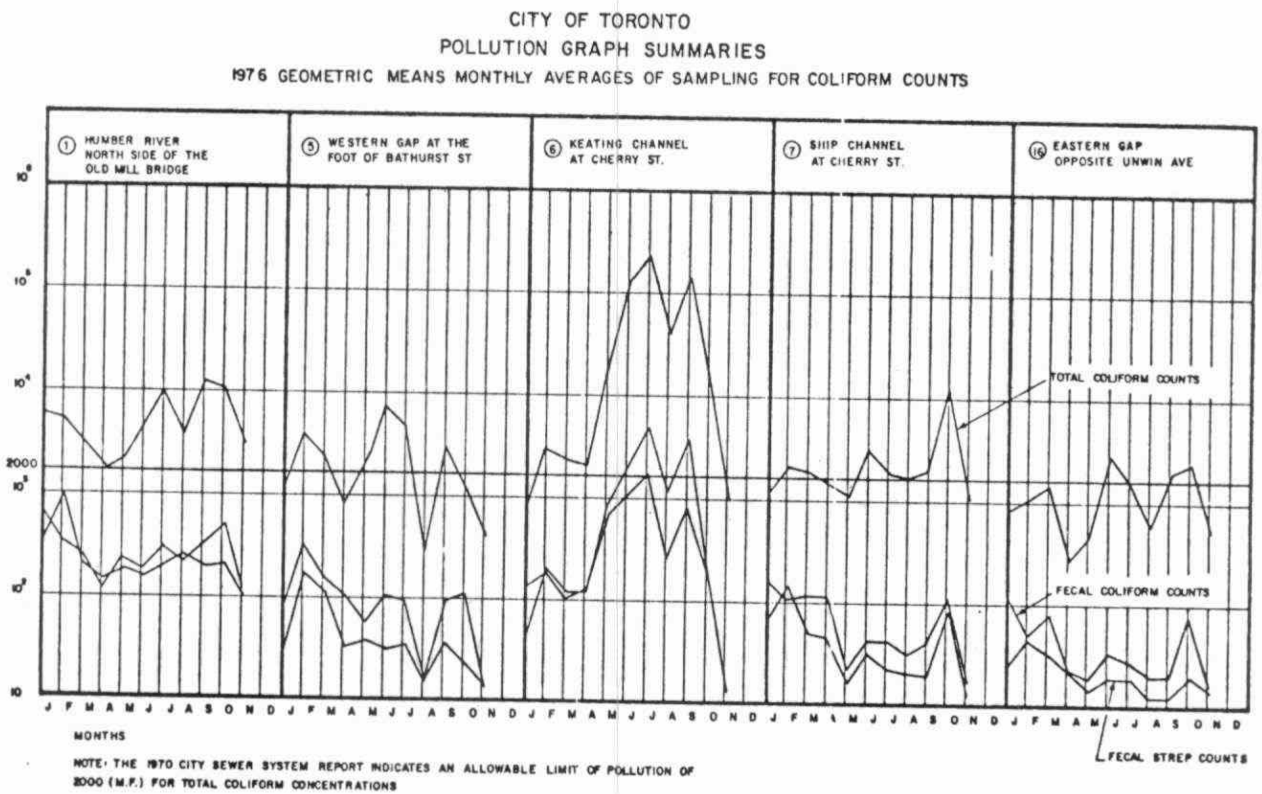
The variations within 1976 at five main Toronto sampling points for total coliform, fecal coliform and fecal strep counts are shown graphically on Figure 6. These graphs, at least, show some reasonable correlation with rainstorms and consequent combined sewer overflow events.

4.9 Programs for Remedying Sewer Problems and Pollution Control

In general, it was found that the work programs for sewer improvements in all six municipalities followed fairly closely the scheduling given in the reports recommending the works. Each municipality, of course, makes additional annual expenditures for items such as sewer inspections and maintenance, pumping stations and plant maintenance, local improvements, etc. The total annual budget for sanitation works, however, tends to be a more or less fixed percentage of the overall municipal budget. In other words, in those times when the overall municipal budget increases, so do the budgets for sanitation works, and the same applies when budget trends are downwards. Because the change in trend is generally gradual, the planning and actual budgeting for sewer remedy programs can be fairly confidently made for five-year periods, as is now common practice. Moreover, budgeting and programming of remedial sewer works in the relevant reports is usually done on a pragmatic basis, i.e., annual expenditures conform to what can be afforded within the sanitation budgets.

Little statistical information was found, however, on the effectiveness of the remedial works after they were carried out. This is usually limited to superficial observations that the works have improved adverse conditions and have provided their intended benefits, simply because prior problems have been reduced or eliminated. Neither the reports nor the observations after work completion provide factual data measuring the beneficial effects in terms of pollution control improvements and/or cost effectiveness. In this respect, modern management practice is still completely absent.

It is appreciated, however, that where reports do not provide "yardsticks" against which the performance of improvements can be measured, there is little incentive for the municipal engineering staff to collect survey information which may show statistically whether the predicted improvement performance has been realized and to what extent.



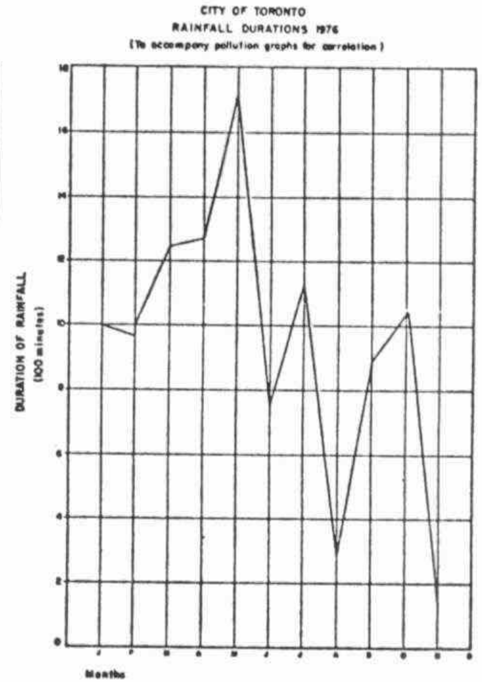


FIGURE 6. POLLUTION INDICATORS SUMMARY FOR CITY OF TORONTO, 1976

5 REVIEW OF COMBINED AND PARTLY COMBINED SEWER PROBLEMS

5.1 Identification of Problems

In Section 3, the replies to the questionnaire received from the 188 municipalities were analyzed in three categories: general information, sewer problems, and correlation between categories and combined sewer systems problems. Nine sewer problems were identified in the questionnaire, along with some additional specific problems obtained from the initial screening of reports received from the municipalities. The questionnaire provided a vehicle for statistical evaluation of the relative frequency, severity and importance of problems occurring within combined or partly combined sewerage systems.

5.2 Viewpoints and Comments

For practical reasons, the requirement under the terms of reference to solicit formally the collective viewpoints of professional associations involved with public works and municipal engineering, and similar viewpoints from relevant branches of the Ontario Ministry of the Environment and federal organizations was curtailed by the Steering Committee for this study. Not only are these viewpoints already well represented on the Urban Drainage Subcommittee, affording a more direct avenue for receiving such opinions, but a general forum was also provided through the conference on "Modern Concepts for Urban Drainage" held in Toronto, Ontario on March 28-29-30, 1977*.

Informal discussions at various interviews with municipal, provincial and federal government authorities, however, provided insight into problems of this nature from the viewpoints of these sources.

5.3 Combined Sewer Overflows and Pollution of Receiving Waters

From the responses to the questionnaire it appeared that, at the municipal level, combined sewer overflows and pollution of recreational waters were not considered to be the severest problems, although of some concern. This does not coincide completely with the concerns of provincial and federal authorities, where the qualitative aspects of pollution due to erosion and combined sewer overflows are given greatest emphasis.

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* Published as Canada-Ontario Agreement Conference Proceedings No. 5.

Yet, from the study findings, it became clear that specific data on combined sewer overflows is still very limited. Most of the efforts to collect and analyze information as a basis for insight into these problems originate from a number of projects sponsored by the provincial and federal governments under the Urban Drainage Subcommittee program of the Canada-Ontario Agreement on Great Lakes Water Quality. Outside these projects there is very little reliable information available in Ontario. Monitoring of combined sewer overflows (and of emergency sanitary bypass flows as well), both with respect to quantity and "storm" overflow water quality, is limited.

The monitoring of pollution, if any, from combined sewer overflows is sometimes complicated by cross connections which allow combined sewers to overflow into storm relief sewers. These cross connections are of particular concern because they make it extremely difficult to pinpoint pollution problems caused by combined sewer overflows.

Existing combined sewer intercepting systems sometimes behave differently than planned because the conditions in the existing combined systems upstream often do not match their assumed theoretical data base. This, in turn, is often caused by the unknown flaws in the system, such as inflow and infiltration, state of maintenance, true flow contributions from the designed inflow sources, and other characteristic sanitary sewer problems.

For these reaons, the results of investigations of case histories on combined sewer overflows, although extremely useful for providing an insight into the extent of these problems, cannot be indiscriminately extrapolated and applied to systems for which inventories of existing conditions are often incomplete.

Computerized mathematical simulation models of sewer systems, as tools for improving accuracy in assessment of combined overflows, are very helpful for evaluating condition variations but, in each case, need calibration and verification from field monitoring studies to ensure that the model matches actual field conditions to a reasonable degree. It should be noted, however, that calibrations for flow quantities matching field conditions are helpful in improving the model accuracy, but attempted calibrations for flow quality have so far not been found to be useful.

In the Chatham case history, reference is made to a U.S. study where it was found that combined sewer overflows, in a good working system, may have contributed a relatively low percentage of the total sanitary wastewater conveyed to treatment. Recent studies in the U.S., however, show that pollution from combined sewer overflows can vary appreciably, with their sanitary sewage contribution ranging from 3 percent to 14 percent of total sanitary flow, and exceeding 10% in most of the cases investigated so far.

Investigations for the City of Toronto waterfront show a certain correlation between periods of heavy rainfall, with consequent overflows, and an increased pollution of receiving waters near the combined outlet points, but this correlation is far from clear cut, as illustrated by the example graphs included with the case history (Appendix F).

Expert knowledge of the matter in general, as well as of the particular combined system considered, is necessary to properly evaluate all relative information available to the investigation.

5.4 General Sewer Problems

5.4.1 Infiltration and inflow

Infiltration and inflow were of concern to most municipalities replying to the questionnaire. Inflow consists of water deliberately directed to the sewer from roof rain water leaders, basement and foundation drains, etc., whereas infiltration consists of groundwater entering the systems through defective pipes and joints. Changing policies on design criteria for storm water runoff have often caused the older combined sewers to be considered overloaded during peak discharge. The base flows from groundwater and sanitary sewage entering the pipes take up a portion of the pipe capacity which, then, is not available for storm water flows. As a result, the combined sewage flow to the treatment plant is diluted and causes hydraulic overloading of sewage treatment plants. In addition, the flow may often exceed the capacity of intercepting manholes which were set to intercept sanitary sewage only, and thus cause overflows directly to the receiving water, even at times other than during storm runoff.

Many municipalities are attempting to have rain water leaders discharge onto the ground to reduce or at least slow the entry of storm water into the sewers.

The detection of improper inflow and unwanted infiltration is receiving more attention. Many municipalities have undertaken inspection by television cameras and smoke-testing to isolate and repair locations where excess water is entering the system. This detection and repair, however, is costly and to some extent can be avoided in new sewers by adequate inspection and testing at the time of installation.

5.4.2 Basement flooding

Perusal of the collected reports and the six case histories indicated that statistics on this problem were appreciably scarcer than expected. Some indication that the incidence of basement flooding may generally increase with the size of municipalities was observed. Since basement flooding is directly related to sewer capacity, there may be some correlation of this problem with certain other conditions. For instance, there is the phenomenon that per capita sewer length is found to decrease when the size of the municipality increases, thus affecting the availability of storm flow storage in sewer systems. It is well known that the proportion of impervious surfaces tends to increase with the size of municipalities, while conveyance capacity increases may be continuously lagging behind the increases in capacity demands.

Very few municipalities appear to keep better than superficial records of basement and yard floodings, or attempt to classify these in groups and correlate them with the known conditions of their sewer systems. Often this problem serves as a warning of possible inadequacies in the system in the area of the floodings.

From the limited information, it appears that such flooding may, in some cases, be more prevalent in areas of combined sewers, but other statistics do not show such a trend. The study findings are, therefore, inconclusive on this matter.

5.4.3 Interconnections

Many municipalities are plagued by erroneous or illegal connections and interconnections. This problem is closely correlated with the historical development of sewer systems and the extent of control exercised over the years. In many instances, interconnections were made to provide a relief for overflows and overloaded sewers.

There are many aspects to the evolution of this problem, of which the following may be mentioned:

a) The conditions under which a private developer or builder connects his drains to the public system affect the problem. Lack of control, misinformation and cost cutting may cause faulty connections or interconnections at one time or another.

b) Lack of adequate municipal standards and basic system information, together with the quality and experience of the public works personnel in the field, may be contributing factors to the creation and continuance of wrong interconnections.

   In the Ottawa case history, some 100 cross connections were found in investigations conducted in 1971-1972. This is an example where correction resulted in a marked reduction of pollution caused by overflows. Without thorough sewer inventories from systematic field surveys, such conditions often remain undetected.

5.4.4 Sewer overloading

Even on the basis of relatively low design parameters, very few existing combined (and storm) sewer systems will have completely satisfactory capacity throughout the system.

It appears that most sewer improvement programs and works are primarily triggered by sewer overloading. Because of its strong correlation with other sewer problems, perhaps it would be better classified as a symptom rather than a problem.

Part of this problem arises because sewer design and construction occurs "after the fact". As a result, there is a time lag between the demands for larger capacity, because of urban development, etc., and the provision of the larger capacity. A major contributing factor to this time lag is often the raising of the necessary funds and the consideration of priorities in this respect. A lack of a clear cut master plan probably contributes to the problem.

5.4.5 Bypassing

In addition to combined sewer overflows, bypassing occurs most commonly as an emergency provision at pumping stations and plants. Additional in-system bypasses to open water or other systems are also fairly common.

Artificial bypasses are seldom continuously monitored so that the evidence of bypassing tends to be incidental or indirect, from water level marks in bypass manholes.

Little or no figures on the extent of this problem are generally available. This often makes it difficult to match design parameters with actual hydraulics in peak flow conditions.

Although construction of emergency bypasses at new facilities is avoided as much as possible in modern sewer practice, bypasses are found in most older larger sewer systems. However, in combined and partly combined sewer systems they effectively act similar to combined sewer overflows and are often indistinguishable from these.

5.4.6 Area flooding

Very little information on this problem was found. Reference should, therefore, be made to the remarks on basement flooding above and to previous sections, with particular reference to the Ottawa case study because Ottawa appeared to keep the most detailed records on flooding occurrences.

5.4.7 Erosion

Again, practically no useful information on this matter came out of this study.

5.5 General Information

With respect to the study objectives of attempting to correlate viewpoints such as historical background, topography, soil conditions, urban population factors, financial factors, etc., no additional information resulted from the studies of the case histories which would add to the discussions in Section 3.

The six case histories, when studied in depth, showed that the system conditions in each municipality tended to be more or less unique.

Although they generally had most of the listed problems and factors in common, this was to such a variable degree and complexity that no well-defined common denominators could be distinguished.

6 OTHER CONSIDERATIONS

6.1 Regulatory Considerations

Included in the study was the collection of information relating to regulatory practices during initial screening. This related primarily to regulatory information at the municipal level.

Sewer by-laws and other regulatory documents, such as official plans, etc., were collected with the sewer reports and questionnaire responses. The sewer by-laws which were collected were turned over to the Steering Committee, at its request, without further perusal and analysis.

Regulatory control involves, primarily, provincial legislation and municipal by-laws. Provincial legislation includes the Planning Act, the Municipal Act, the Ontario Water Resources Act, the Environmental Protection Act, the Conservation Authorities Act and, most recently, the Environmental Assessment Act and, in general, Drainage Law, Common Law and Statute Law. With respect to combined sewer overflows and receiving water pollution, certain federal legislation is involved, including the Fisheries Act and the Canada Water Act.

6.2 Fiscal Considerations

An attempt was made to analyze various financial factors. This was done primarily to see if the impact of the fiscal measures of financial support, as well as any other arrangements between municipal and higher authorities, could be demonstrated and quantified. However, as will be readily appreciated, the great complexity of many other factors influencing sewer works and public works costs, in general, did not allow any such correlation to be recognized.

Undoubtedly, many sewer works programs would have had slower acceptance or been delayed without the availability of government support programs. This is especially true when one considers that the trend of public works costs are a fairly steady percentage of total municipal expenditures. However, the limited financial analysis of this study did not indicate clear differences between the "before and after" years of initiation of certain support programs.

There are, at present, numerous government agencies that provide support which, directly or indirectly, relieves the municipality of some of the financial burden of sewerage works. Because these support programs are well documented and well known by all parties involved in sewerage works, they are listed here only as an overview:

A. Federal support administered by Central Mortgage Housing Corporation:

   Loan and grant system for storm and sanitary trunks, sewage treatment facilities and regional sewerage planning studies

B. Provincial support administered by various Ministries as follows:

   1) Ministry of the Environment

      Loans for certain major storm and sanitary sewerage projects such as trunk sewers and facilities and treatment facilities. (These support programs were formerly under the jurisdiction of the OWRC).

   2) Ministry of Transportation and Communications (formerly Department of Highways of Ontario)

      MTC subsidizes storm water drainage facilities which are part of streets, roads and highway improvement or development.

   3) Ministry of Treasury, Economics and Intergovernmental Affairs:

      Municipal tax assistance or tax exemptions.

   4) Ministry of Agriculture and Food:

      Cost assistance for drainage works involving agricultural lands.

   5) Ministry of Natural Resources

      Financial assistance for the purpose of flood prevention and conservation of water. Such grants relate mainly to dams and reservoir projects and channel improvements.

Authorities under numbers 1), 2) and 3) above all provide support for major sewer works, in which combined sewer systems are involved. Numbers 4) and 5) would seldom be involved in combined sewer system projects.

C. County support:

   Predominantly in rural areas, counties may provide financial assistance where drainage of county road arteries is involved in municipalities.

APPENDIX A

SURVEY QUESTIONNAIRE

APPENDIX A

ENVIRONMENT CANADA - ONTARIO MINISTRY OF THE ENVIRONMENT

COMBINED SEWERAGE SYSTEM PROBLEMS STUDY

QUESTIONNAIRE

1. MUNICIPALITY: ______________________________

2. POPULATION: ____________

3. FURTHER CONTACT (Name, Position and Telephone Number):

______________ ______________ ______________

4. DOES THE MUNICIPALITY HAVE ANY COMBINED SEWERS? YES_____ NO_____

5. ARE THERE ANY SANITARY SEWERS, WHICH ARE INTERCONNECTED TO OR RECEIVE INFLOW OR INFILTRATION FROM STORM WATER, OR ANY OTHER PARTLY COMBINED SEWERS

YES_____ NO_____

6. DO YOU HAVE, OR INTEND TO HAVE, A REMEDIAL PROGRAM SUCH AS SEWER SEPARATION, HOLDING PONDS, ETC. YES_____ NO_____

7. HAVE ANY REPORTS RELEVANT TO THE ABOVE BEEN COMMISSIONED IN THE LAST TEN YEARS?

YES_____ NO_____

8. IF YES, PLEASE LIST REPORT YEAR(S), TITLE AND AUTHOR(S):

9. COPY OF REPORT ENCLOSED? YES_____ NO_____

IF NO, PLEASE INDICATE FROM WHOM A COPY MAY BE OBTAINED.

10. WHAT TYPE OF PROBLEMS DO YOU HAVE WITH YOUR MUNICIPAL DRAINAGE SYSTEM:

a) INFILTRATION AND INFLOW? YES_____ NO_____

b) INTERCONNECTION WITH SEPARATE SANITARY SEWER SYSTEM? YES_____ NO_____

c) BASEMENT FLOODING? YES_____ NO_____

d) LOT OR AREA FLOODING? YES_____ NO_____

e) OVERFLOWS? YES_____ NO_____

f) BY-PASSING? YES_____ NO_____

g) RECREATIONAL WATER POLLUTION? YES_____ NO_____

h) DOWNSTREAM EROSION AND/OR SEDIMENTATION? YES_____ NO_____

i) TREATMENT PLANT OVERLOADING? YES_____ NO_____

j) OTHER (Please specify) YES_____ NO_____

____

____

11. MUNICIPAL REGULATORY PRACTICES:

DO YOU USE MUNICIPAL REGULATIONS TO EFFECT URBAN DRAINAGE PRACTICES THROUGH:

a) SEWER-USE BY-LAW(S)? YES_____ NO_____

b) ZONING BY-LAWS AND OFFICIAL PLANNING? YES_____ NO_____

c) SUBDIVISION AGREEMENTS? YES_____ NO_____

d) MUNICIPAL POLICIES AND STANDARDS? YES_____ NO_____

e) PUBLISHED PROCEDURES FOR DEVELOPERS AND MUNICIPAL STAFF? YES_____ NO_____

f) FISCAL INCENTIVES? YES_____ NO_____

12. COPY OF SUCH DRAINAGE REGULATIONS ENCLOSED? YES_____ NO_____

IF NO, PLEASE INDICATE FROM WHOM SUCH DOCUMENTS MAY BE OBTAINED.

13. ANY ADDITIONAL INFORMATION MAY BE ATTACHED ON SEPARATE SHEET AND WILL BE APPRECIATED.

APPENDIX B

IDENTIFICATION OF COMBINED AND PARTLY COMBINED SEWER SYSTEMS AND THEIR PROBLEMS

APPENDIX B

IDENTIFICATION OF COMBINED AND PARTLY COMBINED SEWER SYSTEMS AND THEIR PROBLEMS

B.1 General Definitions

The 1969 "Glossary - Water and Wastewater Control Engineering" prepared jointly by the WPCF, AWWA, ASCE and APHA provides the following definitions:

Wastewater - The spent water of a community. From the standpoint of source, it may be a combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with any ground water, surface water, and storm water that may be present.

Storm Water - The excess water running off from the surface of a drainage area during and immediately after a period of rain. It is that portion of the rainfall and resulting surface flow that is in excess of that which can be absorbed through the infiltration of the basin.

Combined Wastewater - A mixture of surface runoff and other wastewater such as domestic or industrial wastewater.

Separate System - A system of sewers and drains in which sanitary wastewater and storm water are carried in different conduits.

Sanitary Sewer - A sewer that carries liquid and water-carried wastes from residences, commercial buildings, industrial plants and institutions, together with minor quantities of ground, storm and surface waters that are not admitted intentionally.

Storm Overflow - (1) A weir, orifice, or other device for permitting the discharge from a combined sewer of that part of the flow in excess of that which the sewer is designed to carry.
(2) Some portion of flow due to storm water.

B.2 Partly Combined Sewer System

The title of this study refers to "Combined and Partly Combined Sewerage Systems". From the preceding general definitions a combined sewer system is a system of sewers intentionally designed to receive both wastewater and storm water. A partly combined sewer system is not specifically defined in the 1969 Glossary and this can result in a number of interpretations.

The following two definitions have been derived for utilization with reference to this study:

A partly combined sewer system can be a combination of a system of combined sewers and a separate system of sewers. This condition has generally been a result of expanding municipal development around a core area where separate sanitary sewers in the new area have been connected to discharge into the combined sewers in the core area.

A partly combined sewer can be a combined sewer receiving wastewater and only that portion of the storm water runoff obtained from roofs and/or foundation drains. This condition is generally a result of the construction of separate street storm sewers to pick up overland surface runoff.

In summary, then, a partly combined sewer system may be defined as a system of sewers collecting wastewater and storm water from an area where some portion, but not all, of the storm water runoff is collected in a system of separate storm sewers.

Under peak flow conditions, combined sewers may carry storm water quantities, which are up to 50 to 70 times those of purely dry-weather sanitary sewage.

Partly combined sewers, depending on the type and extent of the components, will carry various flow mixtures during high peak conditions. Descriptions and characteristics of combined, partly combined and separate systems are compared in Table B.1.

B.3 Separate Sewer System

By definition, a separate system carries sanitary wastes and storm water runoff in separate conduits. Also, by definition a separate sanitary sewer may carry "minor quantities of ground, storm and surface wastes that are not admitted intentionally".

TABLE B.1. CLASSIFICATION OF COMBINED AND PARTLY COMBINED SEWERS AS COMPARED WITH SEPARATE STORM AND SANITARY SEWERS

Features	Combined Sewers	Partly Combined Sewers	Interconnected Storm & Sanitary	Separate Storm	Separate Sanitary
A. Flow Mixtures at Peak Flow Conditions	1 part sanitary on 50-70 parts of storm flow.	1 part sanitary on 10-50 parts of storm flow.	1 part sanitary on 5-20 parts of storm flow.	Storm flow with traces of sanitary flow.	Sanitary peak flow 2 to 4 times dry-weather flow.
B. Flow Sources Identification	Serving all storm and sanitary drain connections.	Part of storm flow, mainly from catch basins, collected in separate "street sewers"; sanitary flow plus balance of storm flow in partly combined sewer.	Adjacent separate sewers interconnected intentionally for relief or incidentally such as from major leakage and infiltration.	Except for the odd incorrect sanitary drain connection, storm sewer laterals are connected only. Catch basin connections.	Sanitary flow dilution very limited to normal incidence of inflow and infiltration
C. Other Features	Combined trunk sewers may receive flow from upstream sanitary or storm sewers.	Sometimes original storm sewer receiving sanitary or combined flow from upstream.	Interconnection in system may include sanitary and/or storm sewers draining into combined sewers.	Storm flow only draining to open water by gravity.	Sanitary flow conveyed to sewage treatment nearly always by pumping.
D. Typical Municipal Examples	Survey No. 43 City of Cornwall (most of the older cores in larger municipalities)	Survey No. 215 City of Toronto	Survey No. 25 City of Brockville	Modern suburban development in most municipalities.	

In addition, there are some systems of sewers that were originally designed and built as separate systems but, over the years, have had the two systems interconnected, primarily to provide relief to overloaded trunk sanitary sewers or for some similar reason. Where known, municipalities with this condition have been considered as having a "perverted" separate system and have not been included with the combined sewer systems considered under this study.

B.4 Classification of Sewer Problems

A systematic listing of sewer problems follows in Table B.2. Many of these problems are common to all types of sewers. Others are primarily separate sewer problems, but are considered because they affect partially combined sewers. Many of these are listed as prime problems by the municipalities reporting to have combined and partly combined sewer systems.

TABLE B.2. CLASSIFICATION OF SEWER PROBLEMS

Problem 1 - Hydraulic Overloading

P.1.1 Undersized Sewers

Development exceeds original design parameters.
Incorrect or outdated design parameters.
Inadequate hydraulic design (1)*.
Inadequate construction causes capacities below design.
Structural flaws cause capacities to be reduced in time (2).
Insufficient maintenance causes capacities to be reduced in time (see also P.3).

P.1.2 Excessive Flows

Increase in impervious area causes runoff coefficients to exceed design.
Changes in inlet area characteristics causes design inlet time to be accelerated.
Underdesign of storm flow, from storm frequency selection or incorrect rainfall curves (3).

Problem 2 - Existence of System Bypasses

P.2.1 Design Bypasses

Controlled bypass sewage treatment plant (pumped or gravity flow (=overflow) (4).
Emergency bypass sewage treatment plant.
Bypass at pumping stations

- emergency bypass
- pumped bypass (=overflow)
- controlled or metered bypass (=overflow).

Trunk sewer bypasses (to economize on sewer capacity).
Upper system bypasses, operating under reversed flow conditions only (European practice).

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* For notes (1), (2), etc., see last page of Table.

TABLE B.2 (CONT'D)

P.2.2 Added Bypasses (added at a later stage to overcome recurring flooding problems at minimum expenditure).

Controlled bypasses at treatment or pumping station facilities (=overflows).

System bypasses (added locally, where flooding problems are prevalent).

Incidental bypasses caused by erroneous or illegal connections.

Incidental bypasses caused by partial breakdown, such as in combined manholes.

Problem 3 - Solids Deposition in Sewers

P.3.1 Solids Deposition Caused by Design Flaws

Insufficient sewer grades causing design velocities to go below minimum (min V = 2.0 F.P.S.; for small sewers or areas with high incidence of grit flushing into sewers - min V = 2.5 F.P.S.).

Selection of pipe material or joint types with low C (smoothness) values (5).

Lack of smooth hydraulic alignment: sharp angles; protrusions; improper or no benching in manholes.

P.3.2 Solids Deposition Caused by Below Standard Construction Results or Construction Flaws

Construction of pipes or structures not meeting design specifications with respect to interior smoothness.

Improper connections protruding into flow stream.

Pipes not laid on line and grade.

Insufficient bedding causing pipe settlement (6).

Foreign material (debris) left behind in pipes or manholes.

Incompleted work items such as benching, patching, joint finishing.

TABLE B.2. (CONT'D)

P.3.3 Solids Deposition Caused by Adverse Soil Conditions or Structural Overloading

Adverse soil conditons causing pipes or manholes to exceed expected settlement.
Vibration from increasing heavy truck traffic causing excessive settlement and/or pipe and manhole damage.
Extraneous changes causing settlement or damage, such as from adjacent construction, changes in water table, etc.

P.3.4 Solids Depositon Caused by Changes in Sewer Useage

Flow diversions causing flow quantities and velocities to go below design capacity.
Abnormal types or quantities of solids that settle easily when entering waste stream.
Uncontrolled and incorrect construction of new service connections.

P.3.5 Solids Deposition Caused by Insufficient Maintenance

Incidental only, flushing and rodding of pipes (especially in small and low flow sewers) when plugging occurs.
Insufficient inspection and removal of objects inserted in pipes from vandalism or illegal disposal.
Insufficient inspection and repairs of structural deterioration.

Problem 4 - Infiltration/Inflow Problems

P.4.1 Infiltration Problems

Leaking pipes:

Inferior pipe material.
Cracks from overloading.
Breaks from settlement, improper repairs, extraneous construction of new connections.
Cracks and breaks from improper design or construction.

Leaking connections:

Leaking laterals.

Improper or damaged lateral connections.

Broken connection from settlement or overloading.

Leaking manholes and structures:

Structural design or construction flaws.

Overloading from traffic, etc.

P.4.2 Inflow Problems (Note: these relate to sanitary sewers and partly combined sewers only, as storm sewers and combined sewers by nature are designed to receive storm inflow)

Roof leader connections:

Roof leaders draining to sanitary or partly combined sewers, while connection to local storm drains is possible.

Ditto, while soil conditions afford problem free drainage above surface into gardens or ditches.

Footing drain connections:

Originally pumped footing drains, with pump discharge to drainage courses, ditches or storm sewers, changed to connect to sanitary service drain.

Footing drains illegally connected to sanitary service drain of building.

Footing drain allowed or directed (under applicable by-law, if any) to be connected to sanitary service drain of building.

Other storm water connections to sanitary service drains:

Window well drain connections to sanitary building drains.

Catch basins in below grade pavements, such as sunken driveways connected to sanitary building drains.

Public catch basins in the street connected (incorrectly) to sanitary sewers.

Commercial or industrial building clear water discharge, such as from air conditioning, cooling water, etc., draining into sanitary services or directly to sanitary sewers.

NOTES ON PROBLEM CLASSIFICATION

(1) Inadequate hydraulic design refers to sewer undersizing primarily because of incorrect data basis or calculation errors. These include errors in data on population densities, building densities and area runoff, water consumption information, sewer roughness coefficients, etc.

(2) Structural flaws refers to inadequate design causing passages to become narrowed down or blocked. These flaws include inadequate material specification of pipe and manholes, etc. as well as lack of hydraulic smoothness because of design flaws.

(3) Older rainfall curves are often adapted from those of larger municipalities in identical climate zones. In recent years sufficient rainfall data for all of Canada became available to calculate rainfall curves for most localities in Canada. The most convenient source of this meteorological information is: "Atlas of Rainfall Intensity - Duration Frequency Data for Canada", by J.P. Bruce, Climatological Studies Number 8, Canada Department of Transport, Meteorological Branch.

(4) Sewage flow bypassing of treatment and pumping facilities to open water is usually called "overflow". However, because of frequent misunderstandings of what constitutes a "bypass" and what consitutes an "overflow", the term "bypasses" is used throughout, with "overflows" given in brackets where this term is used more commonly.

(5) Although Kutter's "n" factor is more commonly used in sewer design calculations, the C factor is more universally used in pipe design. In modern sewer design, selection of new pipe material with a poor "C" or "n" value would seldom or never happen. But older sewers often have rough walls and the selection of the correct "C" or "n" value for checking their hydraulic capacity is often based on very limited information.

(6) This item actually covers a host of design and construction considerations. Pipe settlement and failures may be caused by overcutting of trenches, adverse soil conditions, improper pipe laying, etc. to overload the pipe bedding as well as the pipe itself. Oversizing of

bedding and pipe wall strength is often practiced to offset anticipated problems of this nature, considering the workmanship which may be obtained from the contractors and the sewer inspection.

APPENDIX C

SURVEY SUMMARY

TABLE C.1. GENERAL INFORMATION

SURVEY NO.	REF. NO.	MUNICIPALITY	POPULATION 1976 MUNICIPAL DIRECTORY	COMBINED SEWERS		INTER-CONNECTED SANITARY SEWERS		REMEDIAL PROGRAMME		RELEVANT REPORTS			
										COMMISSIONED		REVIEWED	
				Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
1	T12	Ajax #	19,659		x		x		x		x		
2	T93	Alexandria	3,367	x		x		x			x		
3	T86	Alliston	4,004										
4	T89	Almonte	3,650	x		x		x			x		
5	T60	Amherstburg	5,696										
6	T20	Ancaster	14,334		x		x	N.A.			x		
7	TP69	Anderdon	4,912	x		-	-	x		x			x
8	T57	Arnprior	6,109										
9	TP63	Atikokan	5,510										
10	TP54	Augusta	5,921		x		x		x		x		
11	T24	Aurora	13,540										
12	T70	Aylmer	5,030	x		x		x			x		
13	C29	Barrie	33,399		x		x		x		x		
14	T95	Belle River	3,189		x		x		x		x		
15	C28	Belleville	35,089	x		x		x			x		
16	TP47	Blandford-Blenheim	6,579		x		x		x		x		
17	T90	Blenheim	3,619										
18	T100	Blind River	3,000										
19	T48	Bracebridge	7,810	x		x		x		x		x	
20	T77	Bradford	4,566										
21	C12	Brampton	98,590	x		x		x			x		
22	C18	Brantford	65,124		x		x		x		x		
23	TP25	Brantford	9,117		x		x		x		x		
24	TP35	Brock #	8,155	N.A.		-	-	-	-	-	-		
25	C36	Brockville	19,946		x	x		x		x		x	
26	TP59	Burford	5,691		x		x		x		x		
27	C11	Burlington	101,926		x		x		x		x		
28	T11	Caledon #	20,652	N.A.		-	-	-	-	-	-		
29	C15	Cambridge	70,082		x	x		x			x		
30	T91	Campbellford	3,443	x		x		x		x		x	
31	T85	Capreol	4,065										
32	TP61	Caradoc	5,598		x		x		x		x		
33	T68	Carleton Place	5,178		x		x	N.A.		x			x
34	TP64	Charlottenburgh	5,431										
35	C27	Chatham	37,803	x		x		x		x		x	
36	TP40	Chatham	7,182		x		x		x		x		
37	TP65	Clarence	5,429										
38	T96	Clinton	3,139										
39	T32	Cobourg	11,220										
40	T74	Cochrane	4,844	x		x		x		x			x
41	TP73	Colchester South	4,726		x		x	-	-	x			x
42	T36	Collingwood	10,587	x		x		x		x		x	
43	C24	Cornwall	45,743	x		x			x		x		
44	TP74	Cornwall	4,678		x	x			x		x		
45	TP15	Cumberland	11,458		x		x	-	-		x		
46	T62	Deep River	5,485		x		x		x		x		
47	TP8	Delhi-Delhi #	3,598*		x		x		x		x		
48	T107	Dresden	2,416		x		x		x		x		
49	T53	Dryden	6,605										
50	T13	Dundas	19,315		x	x		-	-	x			x
51	T30	Dunnville -Dunnville #	5,471*		x	x		x			x		
		Dunnville -Oswego #	245*		x		x		x		x		
52	T105	Durham	2,511	x		x		x			x		
53	R7	Durham	234,465		x		x	N.A.			x		
54	TP22	East Gwillimbury	9,968		x		x						
55	B5	East York	104,677	x		x		x		x		x	

* Service area population

\# Regional responsibility

TABLE C.1. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	POPULATION 1976 MUNICIPAL DIRECTORY	COMBINED SEWERS		INTER-CONNECTED SANITARY SEWERS		REMEDIAL PROGRAMME		RELEVANT REPORTS			
										COMMISSIONED		REVIEWED	
				Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
56	TP41	East Zorra-Tavistock	7,081		x	x			x		x		
57	TP46	Elizabethtown	6,648		x		x		x		x		
58	T46	Elliot Lake	8,244		x		x		x		x		
59	TP66	Erin	5,352										
60	TP20	Ernestown	10,231		x		x		x		x		
61	T59	Espanola	5,744	x		x		x			x		
62	TP7	Essa	15,325										
63	T66	Essex	5,388	x			x	x			x		
64	B3	Etobicoke	293,753		x	x		x		x			x
65	T92	Exeter	3,390	x			x	x			x		
66	T58	Fergus	5,920	x		x		x			x		
67	TP4	Flamborough #	22,863	N.A.		-	-	-	-	-	-		
68	T104	Forest	2,516		x	-	-	-	-	-	-		
69	T10	Fort Erie	23,072	x		x		x		x			x
70	T43	Fort Frances	9,074	x		x		x		x			x
71	S3	Gananoque	5,176		x	x		-	-	-	-		
72	TP5	Georgina	16,859		x		x		x		x		
73	T99	Geraldton	3,007	x		x		x		x			x
74	TP21	Glanbrook	10,057		x		x		x		x		
75	TP2	Gloucester	53,322		x		x		x		x		
76	T50	Goderich	7,284	x		x		x		-	-		
77	TP42	Gosfield South	6,922										
78	TP13	Goulbourn	12,489		x		x		x		x		
79	T51	Gravenhurst	7,273										
80	T18	Grimsby	15,555										
81	C16	Guelph	68,192		x		x	N.A.		N.A.			
82	T73	Haileybury	4,868	x		x			x		x		
83	T17	Haldimand#-Caledonia	3,474*		x	x		x			x		
		-Cayuga	1,088*		x	x			x		x		
		-Hagersville	2,627*		x	x		x			x		
84	R11	Haldimand-Norfolk	85,840	N.A.		-	-	-	-	-	-		
85	R8	Halton	221,259	N.A.		-	-	-	-	-	-		
86	T4	Halton Hills	33,268		x	x			x		x		
87	C2	Hamilton	311,886	x		x		x			x		
88	TP31	Hamilton	8,321										
89	R3	Hamilton-Wentworth	408,466	x		x		x			x		
90	T67	Hanover	5,329										
91	TP45	Harwich	6,737										
92	T41	Hawkesbury	9,552	x		x		x			x		
93	T71	Hearst	4,998		x	x			x		x		
94	T39	Huntsville	10,149	x		x		x		x			x
95	T47	Ingersoll	8,105										
96	TP9	Innisfil	14,549										
97	T52	Iroquois Falls	6,000*	x		x			x	x			x
98	T27	Kapuskasing	12,543										
99	T106	Kemptville	2,471										
100	T37	Kenora	10,467	x		x			x		x		
101	T87	Kincardine	3,912		x		x	x		x			x
102	TP12	King	13,768		x		x		x		x		
103	C19	Kingston	61,003	x		x		x		x		x	
104	TP3	Kingston	23,448		x		x		x	x			x
105	T78	Kingsville	4,565	x		x		x		x		x	
106	T22	Kirkland Lake	13,895										
107	C7	Kitchener	130,228	x		x		x			x		
108	T34	Leamington	11,012	x		x		x		x		x	
109	T21	Lincoln	14,252	x		-	-	-	-	x		x	
110	T25	Lindsay	13,066	x		x		x		x			x
111	T72	Listowel	4,994										
112	C4	London	243,928	x		-	-	x		x		x	
113	TP52	London	5,957		x		x		x		x		

* Service area population

\# Regional responsibility

TABLE C.1. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	POPULATION 1976 MUNICIPAL DIRECTORY	COMBINED SEWERS		INTER-CONNECTED SANITARY SEWERS		REMEDIAL PROGRAMME		RELEVANT REPORTS			
										COMMISSIONED		REVIEWED	
				Yes		Yes	No	Yes	No	Yes	No	Yes	No
114	TP33	Maidstone	8,200		x		x		x		x		
115	TP71	Malahide	4,806										
116	TP43	March	6,910		x		x		x		x		
117	T2	Markham	53,093		x		x		x		x		
118	T102	Mattawa	2,728	x		x			x	x			x
119	T81	Meaford	4,260	x		x		x			x		
120	TP26	Mersea	8,824		x		x		x		x		
121	T31	Midland	11,331	x		x		x		x			x
122	T15	Milton	18,431		x		x		x		x		
123	C5	Mississauga	234,975		x		x	x		x			x
124	T103	Mitchell	2,706		x		x		x		x		
125	TP29	Moore	8,515		x		x		x	x		x	
126	T94	Mount Forest	3,328										
127	TP58	Murray	5,766		x		x	N.A.		N.A.			
128	R12	Muskoka	33,445	-	-	-	-	-	-	x		x	
129	C37	Nanticoke# -Jarvis	1,098*		x	x		x			x		
		-Port Dover	3,099*	x		x		x		x		x	
		-Waterford	2,388*		x	x		x			x		
130	T75	Napanee	4,804	x		x		x		x		x	
131	TP1	Nepean	74,000		x		x	x		x		x	
132	T5	Newcastle #	30,359	N.A.		-	-	-	-	-	-		
133	T64	New Liskeard	5,461	x		x		x		x		x	
134	T9	Newmarket	24,142										
135	C17	Niagara Falls	67,892										
136	T29	Niagara-on-the-Lake	12,383	x		x		x		x		x	
137	R4	Niagara	358,663	x		x		x		x		x	
138	T26	Nickel Centre #	13,007	N.A.		-	-	-	-	-	-		
139	T16	Norfolk-Port Rowan #	775*		x		x		x		x		
140	C22	North Bay	50,476		x	x			x		x		
141	TP44	North Dorchester	6,777		x		x		x		x		
142	TP70	North Dumfries	4,896										
143	B1	North York	556,044		x	x		-	-	-	-		
144	TP23	Norwich	9,784		x		x		x		x		
145	T1	Oakville	67,634		x	-	-	-	-	-	-		
146	T54	Onaping Falls	6,548										
147	T33	Orangeville	11,179										
148	C33	Orillia	23,911										
149	TP55	Orillia	5,885		x		x	x			x		
150	TP56	Oro	5,819		x		x		x		x		
151	TP32	Osgoode	8,272		x	N.A.		N.A.		N.A.			
152	C10	Oshawa #	102,876		x	x			x		x		
153	C3	Ottawa	302,124	x		x		x		x		x	
154	R2	Ottawa-Carleton	506,592	N.A.		-	-	-	-	-	-		
155	C38	Owen Sound	18,730	x		x		x		x		x	
156	T55	Paris	6,364	x			x	x			x		
157	T63	Parry Sound	5,470	x		x		x			x		
158	R5	Peel	354,317	x		x		x		x			x
159	T40	Pelham	9,834										
160	C39	Pembroke	14,877										
161	T65	Penetanguishene	5,408	x		x		x		x		x	
162	T61	Perth	5,632	x		x		x			x		
163	V1	Petawawa	5,324		x		x	-	-		x		
164	TP37	Petawawa	7,784										
165	C20	Peterborough	59,337		x	x			x		x		
166	T84	Petrolia	4,201										
167	T8	Pickering #	24,758		x	x			x		x		
168	T76	Picton	4,641		x		x	-	-	-	-		
169	TP27	Pittsburgh	8,810		x		x	-	-	-	-		
170	C34	Port Colborne	20,340										
171	T80	Port Elgin	4,463		x	x		x		x			x

* Service area population

\# Regional responsibility

TABLE C.1. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	POPULATION 1976 MUNICIPAL DIRECTORY	COMBINED SEWERS		INTER-CONNECTED SANITARY SEWERS		REMEDIAL PROGRAMME		RELEVANT REPORTS COMMISSIONED		RELEVANT REPORTS REVIEWED	
				Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
172	T42	Port Hope	9,320	x		-	-	x			x		
173	S4	Prescott	4,928	x		x		-	-	x		x	
174	TP60	Raleigh	5,606										
175	T19	Rayside-Balfour #	15,485	N.A.		-	-	-	-	-	-		
176	T45	Renfrew	8,588										
177	T3	Richmond Hill	33,946		x	x		x		x			x
178	TP36	Rideau	7,860		x		x		x		x		
179	T98	Ridgetown	3,076		x		x		x		x		
180	T88	Rockland	3,825										
181	TP72	Russell	4,775		x		x	x			x		
182	C8	St. Catharines	120,398										
183	S5	St. Marys	4,659		x		x		x		x		
184	C30	St. Thomas	26,853	x		x		x		x		x	
185	TP68	Sandwich South	4,950										
186	TP11	Sandwich West	13,896		x		x	x		x		x	
187	C21	Sarnia	55,031	x		x		x		x		x	
188	TP14	Sarnia	11,847										
189	C14	Sault Ste. Marie	79,718		x	x		x		x		x	
190	B2-A2-	Scarborough	372,278	x		x		x		x		x	
191	TP17	Scugog #	10,962	N.A.		-	-	-	-	-	-		
192	V2	Shelburne	2,919		x	x		x			x		
193	TP10	Sidney	14,436		x		x		x		x		
194	TP23	Simcoe #	11,914*		x	x			x		x		
195	T97	Sioux Lookout	3,104		x	x			x	x		x	
196	TP39	Smith	7,260		x		x		x		x		
197	S2	Smiths Falls	9,232	x			x	x		x		x	
198	TP34	South-West Oxford	8,163		x		x		x		x		
199	T5	Stoney Creek	30,011		x		x		x		x		
200	C32	Stratford	24,945		x	x		x		x			x
201	T49	Strathroy	7,471										
202	T56	Sturgeon Falls	6,263	x		x		x			x		
203	C13	Sudbury	97,741		x	x		x			x		
204	R10	Sudbury	166,121		x	x		x			x		
205	TP57	Tay	5,814		x		x		x		x		
206	T69	Tecumseh	5,082		x		x		x		x		
207	TP62	Tecumseth	5,595		x		x		x		x		
208	C40	Thorold	14,694	x		x		x		x		x	
209	C9	Thunder Bay	108,571	x		x		x		x		x	
210	TP51	Thurlow	6,081		x		x		x	x		x	
211	T83	Tilbury	4,215	x		x		x		x			x
212	T44	Tillsonburg	8,974										
213	C26	Timmins	43,988		x		x		x		x		
214	TP49	Tiny	6,387										
215	C1-A1	Toronto	685,333	x		x		x		x		x	
216	R1	Toronto	2,152,269	x		x			x		x		
217	S1	Trenton	14,877		x	x		x		x		x	
218	TP18	Uxbridge #	10,517	N.A.		-	-	-	-	-	-		
219	T14	Valley East	18,949										
220	C35	Vanier	20,146	x		x		x			x		
221	T16	Vaughan	17,402		x		x		x		x		
222	TP67	Vespra	5,125										
223	TP53	Wainfleet	5,933		x		x	-	-	-	-		
224	T38	Walden	10,326										
225	T79	Walkerton	4,512	x		x		x			x		
226	T35	Walaceburg	10,717	x		x		x		x		x	
227	T82	Wasage Beach	4,245		x		x	-	-		x		
228	C23	Waterloo	48,468		x	x			x		x		
229	R	Waterloo	286,281										
230	C25	Welland	44,972										
231	TP50	Wellesley	6,345		x	-	-	-	-	-	-		

* Service area population

\# Regional responsibility

TABLE C.1. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	POPULATION 1976 MUNICIPAL DIRECTORY	COMBINED SEWERS		INTER-CONNECTED SANITARY SEWERS		REMEDIAL PROGRAMME		RELEVANT REPORTS COMMISSIONED		RELEVANT REPORTS REVIEWED	
				Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
232	TP38	West Carleton	7,782		x		x		x		x		
233	TP24	West Lincoln	9,338		x		x	x		x		x	
234	TP48	Westminster	6,440		x		x		x		x		
235	T7	Whitby ‡	27,179	N.A.		-	-	-	-	-	-		
236	T28	Whitchurch-Stouffville	12,423		x		x		x		x		
237	TP19	Wilmot	10,435		x	x			x		x		
238	C6	Windsor	198,569	x		x		x		x			x
239	T101	Wingham	2,841		x		x		x		x		
240	C31	Woodstock	26,137	x		x		x		x		x	
241	TP6	Woolwich	15,827										
242	TP28	Yarmouth	8,637		x		x		x		x		
243	R9	York	195,141	N.A.		-	-	-	-	-	-		
244	B4	York	140,184	x		x		x		x		x	
245	TP30	Zorra	8,480										

S U M M A R Y

		Returned	Not Returned	Pop. (1000) Yes	Pop. (1000) No										
Cities	#	34	6	2,424	1,155	19	15	27	6	24	9	17	16	14	3
	%	85	15	68	32	56	44	82	16	73	27	52	48	82	18
Boroughs	#	5	0	617	850	3	2	5	0	4	0	4	0	3	1
	%	100	0	42	58	60	40	100	0	100	0	100	0	75	25
Towns	#	83	31	302	468	42	36	48	26	42	25	30	43	14	16
	%	73	27	39	61	53	47	64	36	62	38	42	58	47	53
Townships	#	55	19	5	518	1	50	2	46	6	37	8	37	5	3
	%	74	26	1	99	2	98	4	96	14	86	18	82	63	37
Regions including Metro Toronto & District of Muskoka	#	11	1	3,274	401	4	2	6	1	5	1	3	4	2	1
	%	92	8	89	11	67	33	86	4	83	17	43	57	67	33
TOTAL	#	188	57	3,348+	2,991+	69	105	88	79	77	72	62	100	38	24
	%	77	23	51	47	40	60	53	47	52	48	38	62	61	39

\+ Population of Regions not included

* Service area population

‡ Regional responsibility

TABLE C.2. SEWER PROBLEMS

SURVEY NO.	REF. NO.	MUNICIPALITY	INFILTRATION AND INFLOW		INTER-CONNECTION		BASEMENT FLOODING		AREA FLOODING		OVER-FLOWS		BY-PASSING		RECREATIONAL POLLUTION		EROSION		OVER LOADING	
			Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
1		Ajax	x			x		x		x		x		x		x		x		x
2		Alexandria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3		Alliston																		
4		Almonte	x			x	x			x	x		x		x			x		x
5		Amherstburg																		
6		Ancaster		x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7		Anderdon	-	-	-	-	x		-	-	-	-	-	-	-	-	-	-	-	-
8		Arnprior																		
9		Atikokan																		
10		Augusta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11		Aurora																		
12		Aylmer	x		x		x			x	x		x			x		x		x
13		Barrie	x			x		x		x		x		x		x		x	x	
14		Belle River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15		Belleville	x			x		x		x	x		x		x			x	x	
16		Blandford-Blenheim		x		x		x		x		x		x		x		x		x
17		Blenheim																		
18		Blind River																		
19		Bracebridge	x		x		x		x		x		x		x		-	-	x	
20		Bradford																		
21		Brampton	x		-	-	-	-	x		-	-	-	-	-	-	-	-	-	-
22		Brantford	-	-	-	-	x		x		-	-	-	-	-	-	-	-	x	
23		Brantford		x		x		x		x		x		x		x		x		x
24		Brock	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25		Brockville	x		x		x		x		x		x		x		x		x	
26		Burford		x		x		x		x		x		x		x		x		x
27		Burlington	x			x	x		x		-	-	-	-	-	-	-	-	-	-
28		Caledon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29		Cambridge	x			x		x		x		x		x		x		x		x
30		Campbellford	x			x	x			x	x		x			x		x	x	
31		Capreol																		
32		Caradoc		x	-	-		x		x		x		x		x		x		x
33		Carleton Place	x			x	x		x		-	-	-	-	-	-	-	-	x	
34		Charlottenburgh																		
35		Chatham	x		x		x			x	x		x			x	x		x	
36		Chatham	-	-	-	-	x		x		-	-	-	-	-	-	-	-	-	-
37		Clarence																		
38		Clinton																		
39		Cobourg																		
40		Cochrane	x		x			x		x	x		x			x		x	x	
41		Colchester South		x		x	x		x		x		x		x		x			x
42		Collingwood	x		x			x	x		x		x			x	x		x	
43		Cornwall	x		x		x		x		x		x			x		x	x	
44		Cornwall	x			x	x			x	x			x		x		x	x	
45		Cumberland	-	-		x		x		x		x	-	-		x		x	x	
46		Deep River		x		x		x		x		x		x		x		x		x
47		Delhi - Delhi		x		x		x		x		x		x		x		x		x
48		Dresden		x		x		x		x		x		x		x		x		x
49		Dryden																		
50		Dundas	x			x	x			x	x			x		x		x	x	
51		Dunnville -Dunnville	x		x			x		x		x		x		x		x	x	
		-Oswego	x			x		x		x		x		x		x		x		x
52		Durham		x	-	-	x			x		x		x		x	x		x	
53		Durham	x		N.A.		x			x	x		x			x	N.A.		x	
54		East Gwillimbury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55		East York		x	x		x		x		x		x			x		x		x

TABLE C.2. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	INFILTRATION AND INFLOW		INTER-CONNECTION		BASEMENT FLOODING		AREA FLOODING		OVER-FLOWS		BY-PASSING		RECREATIONAL POLLUTION		EROSION		OVER-LOADING	
			Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
56		East Zorra-Tavistock	x			x	x			x	x			x		x		x	x	
57		Elizabethtown	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58		Elliot Lake	x			x		x		x		x		x		x	-	-	x	
50		Erin																		
60		Ernestown	x			x	x		x			x	x			x		x	x	
61		Espanola	x			x	x			x		x		x		x		x		x
62		Essa																		
63		Essex	-	-	-	-	x		x		-	-	-	-	-	-	-	-	x	
64		Etobicoke	x		-	-	x		-	-	-	-	-	-		x	x		-	-
65		Exeter	x			x	x			x		x		x		x		x		x
66		Fergus	x			x		x		x	x		x			x		x	x	
67		Flamborough	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
68		Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
69		Fort Erie	x		x		x		x		x		x		x		x		x	
70		Fort Frances	x			x		x		x		x		x		x		x	x	
71		Gananoque	x		-	-	x		-	-	x		x		-	-	-	-	-	-
72		Georgina	-	-	-	-	-	-	x		-	-	-	-	x		-	-	-	-
73		Geraldton	x		x		x		x		x		x		-	-	x		-	-
74		Glanbrook		x		x		x		x		x		x		x		x		x
75		Gloucester	-	-	-	-	x		-	-	-	-	-	-	-	-	x		-	-
76		Goderich	x		x		x			x	x			x		x		x		x
77		Gosfield South																		
78		Goulbourn		x		x	x			x		x		x		x		x		x
79		Gravenhurst																		
80		Grimsby																		
81		Guelph	x		x		x			x		x		x	x			x		x
82		Haileybury	x		x		x			x	x		x			x		x	x	
		-Caledonia	x		x		x			x	x		x			x		x	x	
83		Haldimand-Cayuga	x			x		x		x		x		x		x		x		x
		-Hagersville	x		x		x		x		x		x		x		x		x	
84		Haldimand-Norfolk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
85		Halton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
86		Halton Hills	x			x	x			x		x		x		x	x		x	
87		Hamilton	x		x		x		x		x		x		x		x		x	
88		Hamilton																		
89		Hamilton-Wentworth	x		x		x		x		x		x		x		x		x	
90		Hanover																		
91		Harwich																		
92		Hawkesbury	x		x		x		-	-	-	-	-	-	-	-	-	-	-	-
93		Hearst	x			x	x		x		x			x		x		x	x	
94		Huntsville	x		x		x			x	-	-	x		x		-	-	x	
95		Ingersoll																		
96		Innisfil																		
97		Iroquois Falls		x		x		x		x		x		x		x		x		x
98		Kapuskasing																		
99		Kemptville																		
100		Kenora	x			x	x		x			x		x		x		x	x	
101		Kincardine		x		x	x		x		x			x		x	x			x
102		King	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
103		Kingston	x			x	x		x		x		x		x			x		x
104		Kingston	x			x	x		x		x			x		x	-	-		x
105		Kingsville	x		x			x		x	x			x		x		x	x	
106		Kirkland Lake																		
107		Kitchener	x			x	x		x		x		x			x	x		x	
108		Leamington	x		x		x		x		x		x		x			x	x	
109		Lincoln	x		-	-	x		-	-	x		-	-	-	-	-	-	x	
110		Lindsay	x		x		x		x		x		x		x		x			x
111		Listowel																		
112		London	x			x	x		x		x		x		x		x		x	
113		London	-	-	-	-	x		x		x		x		-	-	x		-	-

TABLE C.2. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	INFILTRATION AND INFLOW		INTER-CONNECTION		BASEMENT FLOODING		AREA FLOODING		OVER-FLOWS		BY-PASSING		RECREATIONAL POLLUTION		EROSION		OVER-LOADING	
			Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes		Yes	No	Yes	No	Yes	No
114		Maidstone		x		x	x		x			x		x		x		x		x
115		Malahide																		
116		March	-	-	-	-	x		x		x		-	-	-	-	-	-	x	
117		Markham	-	-		x	x		x			x		x		x	x			x
118		Mattawa		x		x		x		x		x		x		x		x		x
119		Meaford	x		x		x		x		x			x		x		x	x	
120		Mersea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
121		Midland	x		-	-	x		x		x		x		x		-	-	x	
122		Milton	x		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
123		Mississauga	-	-	-	-	x		x		-	-	-	-	-	-	x		-	-
124		Mitchell	x			x	-	-		x	-	-	-	-	x			x	x	
125		Moore	x			x		x		x		x		x		x		x	x	
126		Mount Forest																		
127		Murray	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
128		Muskoka	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-Jarvis	x		x		x		x		x		x		x		x			x
129		Nanticoke-Port Dover	x		x			x		x	x		x		x			x	x	
		-Waterford	x		x			x		x		x		x		x		x		x
130		Napanee	x		x			x		x	x		x			x		x	x	
131		Nepean	x			x	x		x		x		x		x		x		x	
132		Newcastle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
133		New Liskeard	x			x		x		x	x		x			x	-	-	-	-
134		Newmarket																		
135		Niagara Falls																		
136		Niagara-on-the-Lake	x		x		x		x		x		x			x	x		x	
137		Niagara	x		x		x		x		x		x		x		x		x	
138		Nickel Centre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
139		Norfolk-Port Rowan		x		x		x		x		x		x		x		x		x
140		North Bay	x			x	x		x		x		x		-	-		x	x	
141		North Dorchester		x		x		x		x		x		x		x		x		x
142		North Dumfries																		
143		North York	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
144		Norwich		x		x		x		x		x		x		x		x		x
145		Oakville	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
146		Onaping Falls																		
147		Orangeville																		
148		Orillia																		
149		Orillia		x		x		x		x		x		x		x		x		x
150		Oro		x		x		x		x		x		x		x		x		x
151		Osgoode	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
152		Oshawa		x		x		x	x			x		x		x	x			x
153		Ottawa	x		x		x		x		x			x	x			x		x
154		Ottawa-Carleton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
155		Owen Sound	x		x		x		x		x		x			x		x	x	
156		Paris		x		x		x		x		x		x		x		x		x
157		Parry Sound	x		x		x			x	x		x			x		x		x
158		Peel	x		x		x		x		x		x		x		x		x	
159		Pelham																		
160		Pembroke																		
161		Penetanguishene	-	-	x		-	-	-	-	-	-	-	-	-	-	-	-	-	-
162		Perth	x		x		x			x	x			x		x		x		x
163		Petawawa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
164		Petawawa																		
165		Peterborough	x		x		x		x		x			x		x		x		x
166		Petrolia																		
167		Pickering		x		x	x			x	x			x		x		x		x
168		Picton	x			x	-	-	-	-	x		x		x		x		x	
169		Pittsburgh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
170		Port Colborne																		
171		Port Elgin	x			x		x	x			x		x		x		x	x	

TABLE C.2. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	INFILTRATION AND INFLOW		INTER-CONNECTION		BASEMENT FLOODING		AREA FLOODING		OVER-FLOWS		BY-PASSING		RECREATIONAL POLLUTION		EROSION		OVER-LOADING	
			Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
172		Port Hope	x			x		x		x		x		x		x		x	x	
173		Prescott	x			x	x			x	x		x			x		x	x	
174		Raleigh																		
175		Rayside-Balfour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
176		Renfrew																		
177		Richmond Hill	x			x	x		x			x		x		x		x		x
178		Rideau	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
179		Ridgetown		x		x	-	-	-	-	-	-	x			x		x		x
180		Rockland																		
181		Russell		x		x		x		x		x		x		x		x		x
182		St. Catharines																		
183		St. Marys		x		x		x	x		x		-	-		x		x		x
184		St. Thomas		x	x		x			x	x		x			x		x	x	
185		Sandwich South																		
186		Sandwich West	-	-	-	-	x		x		-	-	-	-	-	-	-	-	-	-
187		Sarnia	x		x		x			x	x			x	-	-		x		x
188		Sarnia																		
189		Sault Ste. Marie	x			x	x		x		x		x			x		x	x	
190		Scarborough	x		x		x		x		x		-	-	x		x			x
191		Scugog	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
192		Shelburne	x		-	-	x		-	-	-	-	x		-	-	-	-	x	
193		Sidney		x		x		x		x		x		x		x		x		x
194		Simcoe	x			x		x		x		x		x		x		x		x
195		Sioux Lookout	x			x		x		x		x		x		x		x	x	
196		Smith		x		x		x		x		x		x		x		x		x
197		Smiths Falls	x			x	x		x		x			x	x			x	x	
198		South-West Oxford		x		x		x		x		x		x		x		x		x
199		Stoney Creek	x			x	x			x		x		x		x		x	-	-
200		Stratford	x		x			x		x		x		x		x		x	x	
201		Strathroy																		
202		Sturgeon Falls	x		x		x		-	-	x		x		-	-	-	-	x	
203		Sudbury	x			x		x		x	x		x		x			x		x
204		Sudbury	x			x		x		x	x		x		x			x		x
205		Tay		x		x		x		x		x		x		x		x		x
206		Tecumseh	x			x		x		x		x		x		x		x		x
207		Tecumseth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
208		Thorold	x		x		x			x	x		-	-		x		x		x
209		Thunder Bay	x		x		x		-	-	x		x		-	-	-	-	x	
210		Thurlow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
211		Tilbury	x		x		x			x		x		x		x		x	x	
212		Tillsonburg																		
213		Timmins	x			x	x		x			x		x	x		x		x	
214		Tiny																		
215		Toronto	x		x		x		x		x			x	x		x		-	-
216		Toronto		x	x			x		x	x		x		x			x		x
217		Trenton	x			x		x		x	x		x			x		x	x	
218		Uxbridge	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
219		Valley East																		
220		Vanier	x			x	x			x		x		x		x		x		x
221		Vaughan	x			x	x		x			x		x		x		x		x
222		Vespra																		
223		Wainfleet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
224		Walden																		
225		Walkerton	x		x		-	-	-	-	-	-	-	-	-	-	-	-	x	
226		Wallaceburg	x		-	-		x		x	x			x		x		x	x	
227		Wasage Beach	-	-	-	-	x		x		-	-	-	-	-	-	-	-	-	-
228		Waterloo	x			x		x		x	x		x			x	x		x	
229		Waterloo																		
230		Welland																		
231		Wellesley	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE C.2. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	INFILTRATION AND INFLOW Yes	INFILTRATION AND INFLOW No	INTER-CONNECTION Yes	INTER-CONNECTION No	BASEMENT FLOODING Yes	BASEMENT FLOODING No	AREA FLOODING Yes	AREA FLOODING No	OVER-FLOWS Yes	OVER-FLOWS No	BY-PASSING Yes	BY-PASSING No	RECREATIONAL POLLUTION Yes	RECREATIONAL POLLUTION No	EROSION Yes	EROSION No	OVER-LOADING Yes	OVER-LOADING No
232		West Carleton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
233		West Lincoln	x			x		x		x		x		x		x		x		x
234		Westminster		x		x		x		x		x		x		x		x		x
235		Whitby	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
236		Whitchurch-Stouffville	x			x		x		x		x		x		x		x	x	
237		Wilmot	x			x	x		x		x			x		x		x	x	
238		Windsor	x		x		x		x		x		x			x		x		x
239		Wingham	-	-	-	-	x		-	-	x		-	-	-	-	-	-	-	-
240		Woodstock	x		x		x		x		x		x		x			x	x	
241		Woolwich																		
242		Yarmouth		x		x		x		x		x		x		x		x		x
243		York	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
244		York		x	x		x			x	x			x		x		x	-	-
245		Zorra																		

SUMMARY

		Returned	Not Returned																		
Cities	#	34	6	30	2	17	14	25	8	19	14	23	7	19	10	13	14	10	20	18	16
	%	85	15	94	6	55	45	76	24	58	42	77	23	66	34	48	52	33	67	53	47
Boroughs	#	5	0	2	2	3	0	4	0	2	1	3	0	1	1	1	3	2	2	1	1
	%	100	0	50	50	100	0	100	0	67	33	100	0	50	50	25	75	50	50	50	50
Towns	#	83	31	57	11	24	28	42	24	21	40	36	25	26	35	10	49	10	45	40	23
	%	73	27	84	16	46	54	64	36	34	66	59	41	43	57	17	83	18	82	63	37
Townships	#	55	19	8	21	0	29	15	21	11	24	8	24	4	26	3	28	4	27	8	23
	%	74	26	28	72	0	100	42	58	31	69	25	75	13	87	10	90	23	77	26	74
Regions	#	11	1	5	1	4	1	4	2	3	3	6	0	6	0	5	1	3	2	4	2
	%	92	8	83	17	80	20	67	33	50	50	100	0	100	0	83	17	60	40	67	33
TOTAL	#	188	57	102	37	48	72	90	55	56	82	76	56	56	72	32	95	29	96	71	65
	%	77	23	73	27	40	60	62	38	41	59	58	42	44	56	25	75	23	77	52	48

TABLE C.3. REGULATIONS FOR SEWERS

SURVEY NO.	REF. NO.	MUNICIPALITY	BY-LAWS		PLANNING		AGREEMENTS SUBDIVISION		STANDARDS		MUNICIPAL PROCEDURES		FISCAL INCENTIVES		REGULATIONS RECEIVED	
			Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
1		Ajax	x		x		x		x		x			x		x
2		Alexandria	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3		Alliston														
4		Almonte		x	x		x			x		x		x		x
5		Amherstburg														
6		Ancaster	x		-	-	x		x		x		-	-		x
7		Anderdon	x		x		-	-	-	-	-	-	-	-	-	-
8		Arnprior														
9		Atikokan														
10		Augusta	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11		Aurora														
12		Aylmer	x			x	x		x			x		x	x	
13		Barrie	x		x		x		x			x		x	x	
14		Belle River	x		-	-	-	-	-	-	-	-	-	-		x
15		Belleville	x		x		x		x		x			x	x	
16		Blandford-Blenheim		x	x		x		x			x		x		x
17		Blenheim														
18		Blind River														
19		Bracebridge	x			x	x		x			x		x		x
20		Bradford														
21		Brampton	x		x		x		x		x		-	-	x	
22		Brantford	x		x		x		x		x		-	-	-	-
23		Brantford	x		x		x		x		x			x		x
24		Brock	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25		Brockville	x		x		x		x		x			x		x
26		Burford		x	x		x			x		x		x		x
27		Burlington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28		Caledon	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29		Cambridge	x		-	-	x		x		x			x		x
30		Campbellford	x		x		x		x			x	x			x
31		Capreol														
32		Caradoc		x	x		x		x			x		x		x
33		Carleton Place	x		x		x		-	-	-	-	-	-	-	-
34		Charlottenburgh														
35		Chatham	x		x		x		x		x			x		x
36		Chatham	-	-	x		x		-	-	-	-	-	-		x
37		Clarence														
38		Clinton														
39		Cobourg														
40		Cochrane	x		x		x		x			x		x		x
41		Colchester South	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42		Collingwood	x		x		x		x		x			x	x	
43		Cornwall	x		x		x		x			x		x	x	
44		Cornwall	x			x	x			x		x		x		x
45		Cumberland		x		x	x			x		x		x		x
46		Deep River	-	-	x		x		-	-	-	-	-	-		x
47		Delhi - Delhi	x		x		x		x		x		x		x	
48		Dresden	x		-	-	x		-	-	-	-	-	-	-	-
49		Dryden														
50		Dundas	x		x		x		x		x			x		x
51		Dunnville -Dunnville -Oswego	x x		x x		x x		x x		x x		x x		x x	
52		Durham		x		x		x		x		x		x	-	-
53		Durham	x		N.A.		x			x		x		x	-	-
54		East Gwillimbury	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55		East York	x		x		x		x			x		x		x

TABLE C.3. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	BY-LAWS		PLANNING		AGREEMENTS SUBDIVISION		STANDARDS		MUNICIPAL PROCEDURES		FISCAL INCENTIVES		REGULATIONS RECEIVED	
			Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
56		East Zorra-Tavistock	x		x		x		x		x			x	x	
57		Elizabethtown	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58		Elliot Lake		x		x		x		x		x		x		x
59		Erin														
60		Ernestown	x		x		x			x		x		x		x
61		Espanola		x	x		x		x			x		x	-	-
62		Essa														
63		Essex	-	-	x		x		-	-	-	-	-	-	-	-
64		Etobicoke	x		x		x		x		x		-	-		x
64		Exeter	x		x		x			x		x		x		x
66		Fergus	x		x		x		x		x			x	x	
67		Flamborough	-	-	-	-	-	-	-	-	-	-	-	-	-	-
68		Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-
69		Fort Erie	x		x		x		x		x		x			x
70		Fort Frances	x		x		x		x			x	-	-		x
71		Gananoque	x		-	-	-	-	-	-	-	-	-	-	-	-
72		Georgina	x		x		x		x		x			x		x
73		Geraldton	x			x		x	x			x		x		x
74		Glanbrook		x		x	x			x		x		x		x
75		Gloucester	x		x		x		x		-	-	-	-		x
76		Goderich	x		x		x		x		x		x		x	
77		Gosfield South														
78		Goulbourn	x			x	x			x		x		x	x	
79		Gravenhurst														
80		Grimsby														
81		Guelph	x		x		x		x		x			x	x	
82		Haileybury		x		x		x		x		x		x		x
		-Caledonia	x		x		x		x		x		x		x	
83		Haldimand-Cayuga	x		x		x		x		x		x		x	
		- Hagersville	x		x		x		x		x		x		x	
84		Haldimand-Norfolk	x		x		x		x		x		x		x	
85		Halton	-	-	-	-	-	-	-	-	-	-	-	-	-	-
86		Halton Hills	x			x	x		x			x	-	-	x	
87		Hamilton	x		x		x		x			x		x	x	
88		Hamilton														
89		Hamilton-Wentworth	x		x		x		x			x		x		x
90		Hanover														
91		Harwich														
92		Hawkesbury		x	x		x			x		x		x		x
93		Hearst	x		x		x		x			x		x	x	
94		Huntsville	x		x		x		-	-	x		-	-	x	
95		Ingersoll														
96		Innisfil														
97		Iroquois Falls	x		x		x		x		x			x	x	
98		Kapuskasing														
99		Kemptville														
100		Kenora		x		x	x			x		x		x		x
101		Kincardine		x	x		x			x	x			x		x
102		King	-	-	-	-	-	-	-	-	-	-	-	-	-	-
103		Kingston	x		x		x		x			x		x	x	
104		Kingston	x		x		x		x		x			x	x	
105		Kingsville	x		x		x		x			x		x		x
106		Kirkland Lake														
107		Kitchener		x		x	x		x		x		x			x
108		Leamington	x		x		x		x		x			x		x
109		Lincoln	-	-	-	-	-	-	-	-	-	-	-	-	-	-
110		Lindsay	x		x		x		x		x			x		x
111		Listowel														
112		London	x		x		x		x		x		x		x	
113		London	-	-	-	-	x		-	-	-	-	-	-		x

TABLE C.3. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	BY-LAWS		PLANNING		AGREEMENTS SUBDIVISION		STANDARDS		MUNICIPAL PROCEDURES		FISCAL INCENTIVES		REGULATIONS RECEIVED	
			Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
114		Maidstone	N.A.		x		x		x			x		x		x
115		Malahide														
116		March	x		x		x		x		x		x			x
117		Markham	x		x		x		x		x		x			x
118		Mattawa		x		x		x		x		x		x		x
119		Meaford	x		x		x		x		x			x		x
120		Mersea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
121		Midland	x		x		x		x		x			x	x	
122		Milton	x		x		x		-	-	-	-	-	-		x
123		Mississauga	x		x		x		x		x		-	-		x
124		Mitchell	x		x		x		x		-	-	-	-	x	
125		Moore	x		x		x		x		x			x	x	
126		Mount Forest														
127		Murray	-	-	-	-	-	-	x	-	-	-	-	-	-	-
128		Muskoka	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-Jarvis	x		x		x		x		x		x		x	
129		Nanticoke-Port Dover	x		x		x		x		x		x		x	
		-Waterford	x		x		x		x		x		x		x	
130		Napanee	x		x		x		x		x		x		x	
131		Nepean	x		x		x		x		x			x	x	
132		Newcastle	-	-	-	-	-	-	-	-	-	-	-	-	-	-
133		New Liskeard		x		x	x		x		-	-		x		x
134		Newmarket														
135		Niagara Falls														
136		Niagara-on-the-Lake	x		x		x		x			x		x	x	
137		Niagara	x			x		x	x			x		x	x	
138		Nickel Centre	-	-	-	-	-	-	-	-	-	-	-	-	-	-
139		Norfolk-Port Rowan	x		x		x		x		x		x		x	
140		North Bay	x		x		x		x		x			x		x
141		North Dorchester	-	-	-	-	x		-	-	-	-	-	-		x
142		North Dumfries														
143		North York	-	-	-	-	-	-	-	-	-	-	-	-	-	-
144		Norwich	x		x		x		x			x		x		x
145		Oakville	-	-	-	-	-	-	-	-	-	-	-	-	-	-
146		Onaping Falls														
147		Orangeville														
148		Orillia														
149		Orillia		x		x	x			x		x		x		x
150		Oro		x	x		x		x		x			x	x	
151		Osgoode	-	-	-	-	-	-	-	-	-	-	-	-	-	-
152		Oshawa		x		x	x		x		x		-	-		x
153		Ottawa	x		x		x		x			x		x		x
154		Ottawa-Carleton	-	-	-	-	-	-	-	-	-	-	-	-	-	-
155		Owen Sound	x		x		x		x		x			x		x
156		Paris	x		x		x		x			x		x		x
157		Parry Sound	x		x		x		x			x		x		x
158		Peel	x		x		x		x		x			x		x
159		Pelham														
160		Pembroke														
161		Penetanguishene	x		x		x		x		x		-	-	-	-
162		Perth	x		x		x		x			x		x	x	
163		Petawawa	x		x		x			-	-	-	-	-	x	
164		Petawawa														
165		Peterborough	x			x	x		x		x			x	x	
166		Petrolia														
167		Pickering	x		-	-	x		x		-	-	-	-		x
168		Picton	x		x		x		x		-	-		x		x
169		Pittsburgh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
170		Port Colborne														
171		Port Elgin	x		x		x		x		x			x	x	

TABLE C.3. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	BY-LAWS		PLANNING		AGREEMENTS SUBDIVISION		STANDARDS		MUNICIPAL PROCEDURES		INCENTIVES		REGULATIONS RECEIVED	
			Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
172		Port Hope	x		x		x		x		x		-	-	-	-
173		Prescott	x		x		x		x			x		x		x
174		Raleigh														
175		Rayside-Balfour	-	-	-	-	-	-	-	-	-	-	-	-	-	-
176		Renfrew														
177		Richmond Hill	x			x	x		x			x		x	x	
178		Rideau	-	-	-	-	-	-	-	-	-	-	-	-	-	-
179		Ridgetown	x		x		x		x			x		x		x
180		Rockland														
181		Russell		x	x		x		x		-	-	x			x
182		St. Catharines														
183		St. Marys	x		x		x		x		x			x		x
184		St. Thomas	x			x	x		x		x			x	x	
185		Sandwich South														
186		Sandwich West	x		x		x		x		x		-	-	-	-
187		Sarnia	x		-	-	x		-	-		x		x	x	
188		Sarnia														
189		Sault Ste. Marie	x		x		x		x			x		x	x	
190		Scarborough	x		x		x		x		x			x	x	
191		Scugog	-	-	-	-	-	-	-	-	-	-	-	-	-	-
192		Shelburne	x		-	-	x		-	-	-	-	-	-	-	-
193		Sidney	x		x		x			x		x		x		x
194		Simcoe	x		x		x		x				x		x	
195		Sioux Lookout		x		x		x	x			x	-	-		x
196		Smith		x		x	x			x		x		x	x	
197		Smiths Falls	x			x	x		x			x		x	x	
198		South-West Oxford		x		x		x		x		x		x		x
199		Stoney Creek	x		x		x		x		x		x			x
200		Stratford	x		x		x		x		x			x		x
201		Strathroy														
202		Sturgeon Falls	x			x		x		x		x		x		x
203		Sudbury	x			x	x		x			x		x		x
204		Sudbury	x			x	x		x			x		x		x
205		Tay		x	x		x		x			x		x		x
206		Tecumseh	x		x		x			x		x		x		x
207		Tecumseth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
208		Thorold	x			x	x		x		x			x	x	
209		Thunder Bay	-	-	-	-	x		x		-	-	-	-	x	
210		Thurlow	-	-	-	-	-	-	-	-	-	-	-	-	-	-
211		Tilbury	x		x		x		-	-		x		x	x	
212		Tillsonburg														
213		Timmins	x		x		x		x		x			x		x
214		Tiny														
215		Toronto	x		x		x		x			x	x		x	
216		Toronto	x		-	-	-	-	-	-	-	-	-	-	x	
216		Trenton	x		x		x		x			x	-	-	x	
218		Uxbridge	-	-	-	-	-	-	-	-	-	-	-	-	-	-
219		Valley East														
220		Vanier	x		x			x		x		x		x	x	
221		Vaughan	x		x		x		x			x		x	x	
222		Vespra														
223		Wainfleet	-	-	-	-	-	-	-	-	-	-	-	-	-	-
224		Walden														
225		Walkerton	x		x		x		x		-	-	-	-		x
226		Wallaceburg	x		x		x			x		x		x	x	
227		Wasaga Beach	x		x		x		x		-	-	-	-	-	-
228		Waterloo	x		x		x		-	-	-	-	-	-		x
229		Waterloo														
230		Welland														
231		Wellesley	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE C.3. (CONT'D)

SURVEY NO.	REF. NO.	MUNICIPALITY	BY-LAWS Yes	BY-LAWS No	PLANNING Yes	PLANNING No	AGREEMENTS SUBDIVISION Yes	AGREEMENTS SUBDIVISION No	STANDARDS Yes	STANDARDS No	MUNICIPAL PROCEDURES Yes	MUNICIPAL PROCEDURES No	FISCAL INCENTIVES Yes	FISCAL INCENTIVES No	REGULATIONS RECEIVED Yes	REGULATIONS RECEIVED No
232		West Carleton	-	-	-	-	-	-	-	-	-	-	-	-	-	-
233		West Lincoln	x		x		x		x		x			x	x	
234		Westminster		x	x		x			x		x		x		x
235		Whitby	-	-	-	-	-	-	-	-	-	-	-	-	-	-
236		Whitchurch-Stouffville	x		x		x		x			x		x		x
237		Wilmot	x		x		x		x			x		x		x
238		Windsor	x			x	x		x		x			x	x	
239		Wingham		x	x		x			x		x		x		x
240		Woodstock	x			x	x			x	-	-		x	x	
241		Woolwich														
242		Yarmouth		x		x		x		x		x		x		x
243		York	x		-	-	-	-	-	-	-	-	-	-		x
244		York	x		x		-	-	x			x		x		x
245		Zorra														

S U M M A R Y

		Returned	Not Returned	BY-LAWS Yes	BY-LAWS No	PLANNING Yes	PLANNING No	AGREEMENTS SUBDIVISION Yes	AGREEMENTS SUBDIVISION No	STANDARDS Yes	STANDARDS No	MUNICIPAL PROCEDURES Yes	MUNICIPAL PROCEDURES No	FISCAL INCENTIVES Yes	FISCAL INCENTIVES No	REGULATIONS RECEIVED Yes	REGULATIONS RECEIVED No
Cities	#	34	6	32	2	22	8	32	1	29	2	20	10	4	23	18	13
	%	85	15	94	6	73	27	97	3	94	6	67	33	15	85	58	42
Boroughs	#	5	0	4	0	4	0	3	0	4	0	2	1	0	2	1	2
	%	100	0	100	0	100	0	100	0	100	0	67	33	0	100	33	67
Towns	#	83	31	60	12	54	14	65	7	50	13	24	35	9	44	24	40
	%	73	27	83	17	79	21	90	10	79	21	41	59	17	83	38	62
Townships	#	55	19	19	13	26	8	33	2	20	12	12	18	4	26	10	24
	%	74	26	59	41	76	26	94	6	63	37	40	60	13	87	29	71
Regions	#	11	1	8	0	4	2	5	1	6	1	2	5	1	6	3	4
	%	92	8	100	0	67	33	83	17	86	14	29	71	14	86	43	57
TOTAL	#	188	57	123	27	110	32	138	11	109	28	60	68	18	101	56	83
	%	77	23	82	18	77	23	93	7	80	20	47	53	15	85	40	60

APPENDIX D

ECONOMIC AND POPULATION FACTORS

APPENDIX D

ECONOMIC AND POPULATION FACTORS

D.1 Economic Base Considerations in General

An attempt has been made to compare the economic bases of municipalities reporting combined sewer systems and those with separate sewer systems. Figures D.1 and D.2 attempt to indicate development of assessment, taxation, etc. for comparison of these two groups. They show, however, little or no significant difference in assessment, taxation, etc., with and without combined sewer system development (and separation programs).

Although it stands to reason that there are economics of construction for combined sewer system decisions, this type of installation has involved many other factors as well. The assembled statistics do not show that the low income municipalities are first to adopt combined sewerage development.

D.2 Further Analysis of Ontario and Case History Background

As is further discussed in Appendix F, the economic base factors of assessment, taxation and sanitary services costs have been compared in further detail between the "case history" municipalities and Ontario as a whole. Certain interesting economic trends became apparent, but there is no apparent relationship between these economic base factors and construction of combined sewer systems.

Figure D.3 shows graphs of the financial factor analysis of the province of Ontario on a per capita and constant dollar basis, to amplify trends. Figure D.3 is presented as a basis for comparison of such analysis with that of the six case history municipalities.

D.3 General Trends

The constant dollar basis in Figures D.3, D.4, etc. has been calculated by dividing the per capita costs of each year by the Southhham Construction Index - Composite Series for Ontario.

In Figure D.3 it can be seen that the annual sanitation expenditures more or less keep pace with taxation, i.e. overall municipal expenditures. The drop, on a per capita - constant dollar basis of all financial factors during the war years and post-war decade, followed by a rise during recent years with the development of modern water pollution control, is evident. A more recent drop down to the period average may reflect the present downward trend in overall economic prosperity.

No significant trends with respect to work on overcoming combined sewer problems became apparent, however.

D.4 Urban Population and Densities Considerations

As is well documented in countless papers on urban sewerage, storm water runoff, etc., and also in the perused reports, most larger municipalities continuously struggle to keep up with the ever increasing sewage quantities. Growth in physical size, higher population densities, re-development and surface improvements in the core area are all factors causing existing sewers to become over-taxed.

With continuous sewer extension, the sewer networks form chains, which have a mottled pattern of capacity relative to present design standards. In the few completely comprehensive surveys of sewer systems for entire municipalities carried out in Ontario, it was found that existing sewer capacity ranged widely from 8 percent to over 100 percent of the theoretically required capacity.

Separation of combined sewers, therefore, is often justifiable because if they are converted to sanitary or partly combined sewers by building new storm sewers in the street, at least adequate capacity is obtained for many years to come.

Building densities tend to increase towards the core area in larger cities because of the prevalance of office buildings, etc., in the heart of the cities.

The reports listed in Appendix E give the overall present population densities for the relevant municipalities, which are found to be relatively well below those assumed in sewer design. Core densities, however, which are of most interest when considering combined sewer problems, usually exceed the original design values by a good margin.

Municipalities reported to have combined sewer systems have the average population densities shown in Table D.1.

TABLE D.1. POPULATION DENSITIES

Population	persons/acre
A. Municipalities larger than 100,000 population	12.5
B. Municipalities with 100,000 to 20,000 population	7.2
C. Municipalities with 20,000 to 10,000 population	2.3
D. Municipalities with 15,000 to 5,000 population	3.1
E. Municipalities with 5,000 to 2,500 population	3.1

The variations within each group are large, however, and statistically there appears to be little or no difference between the above and those of municipalities without combined sewer systems.

D.5 Population Development Factors

As combined sewer systems and general sewer development are closely correlated to population growth factors and trends, such growth and population development were examined as background information.

Firstly, the following general population growth rates are of interest because they show the discussed development differences before and after World War II.

TABLE D.2. POPULATION GROWTH RATES

	Average Annual Growth Rates	
	Period from 1926 to 1940	Period from 1940 to 1975
Province of Ontario	1.2%	2.4%
Cities (and Boroughs)	1.6%	3.5%
Towns and Villages	0.8%	1.9%
Townships	0.9%	0.4%

From the above numbers it appears that the overall municipal growth in Ontario after the War was twice that before and that the growth of the cities and larger towns accelerated rapidly. This may have aggravated the problem with combined sewers, which are predominantly located in the core areas of the cities and larger towns.

Statistics derived from the survey afford a somewhat more detailed consideration of such factors in Table D.3.

The figures of Item (8) in Table D.3 indicate that outright combined sewer systems are most prevalent in cities over 100,000 population. The incidence of the number of reports received for perusal from municipalities in this population range confirmed this trend.

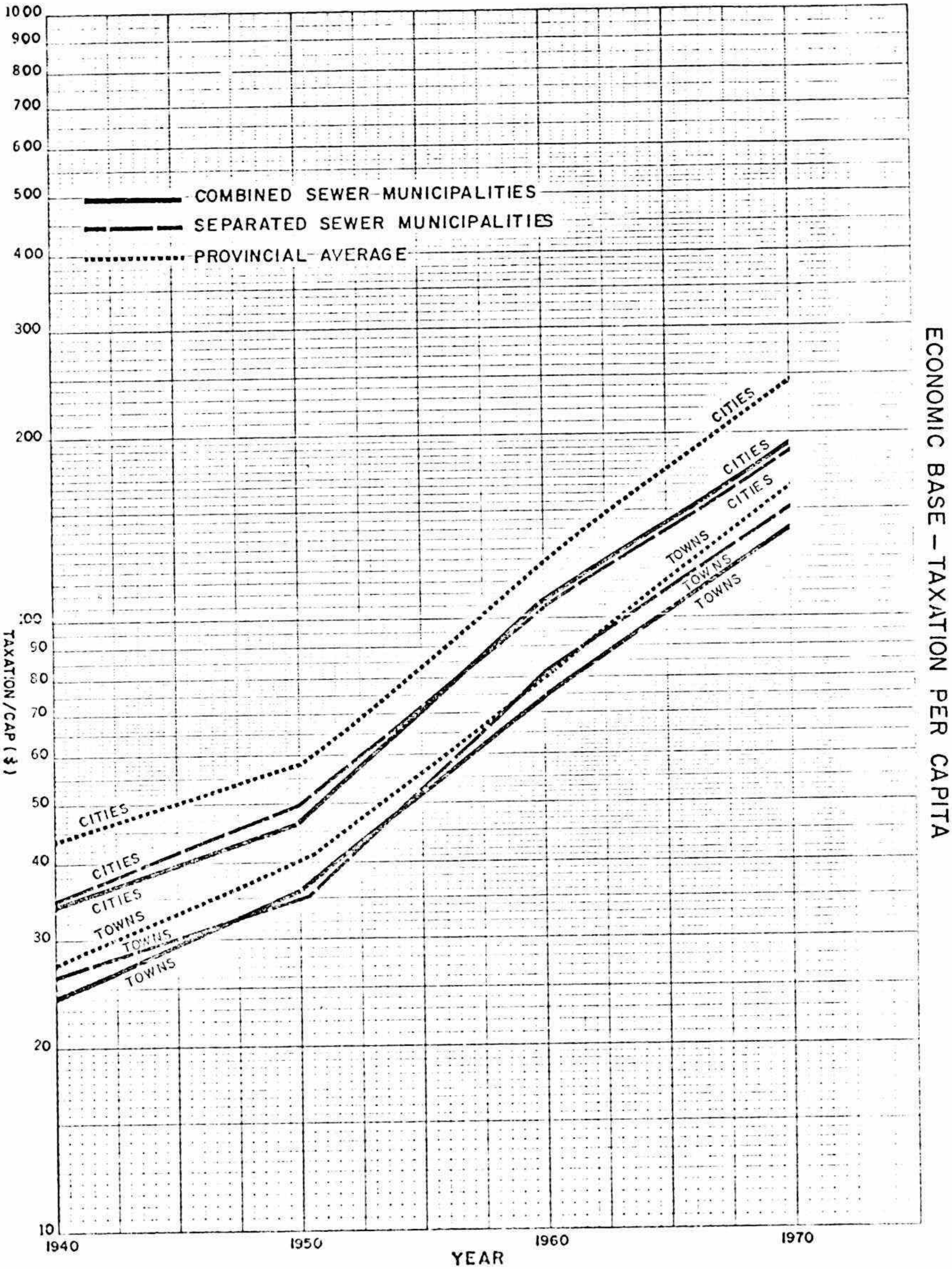


FIGURE D.1. ECONOMIC BASE - TAXATION PER CAPITA

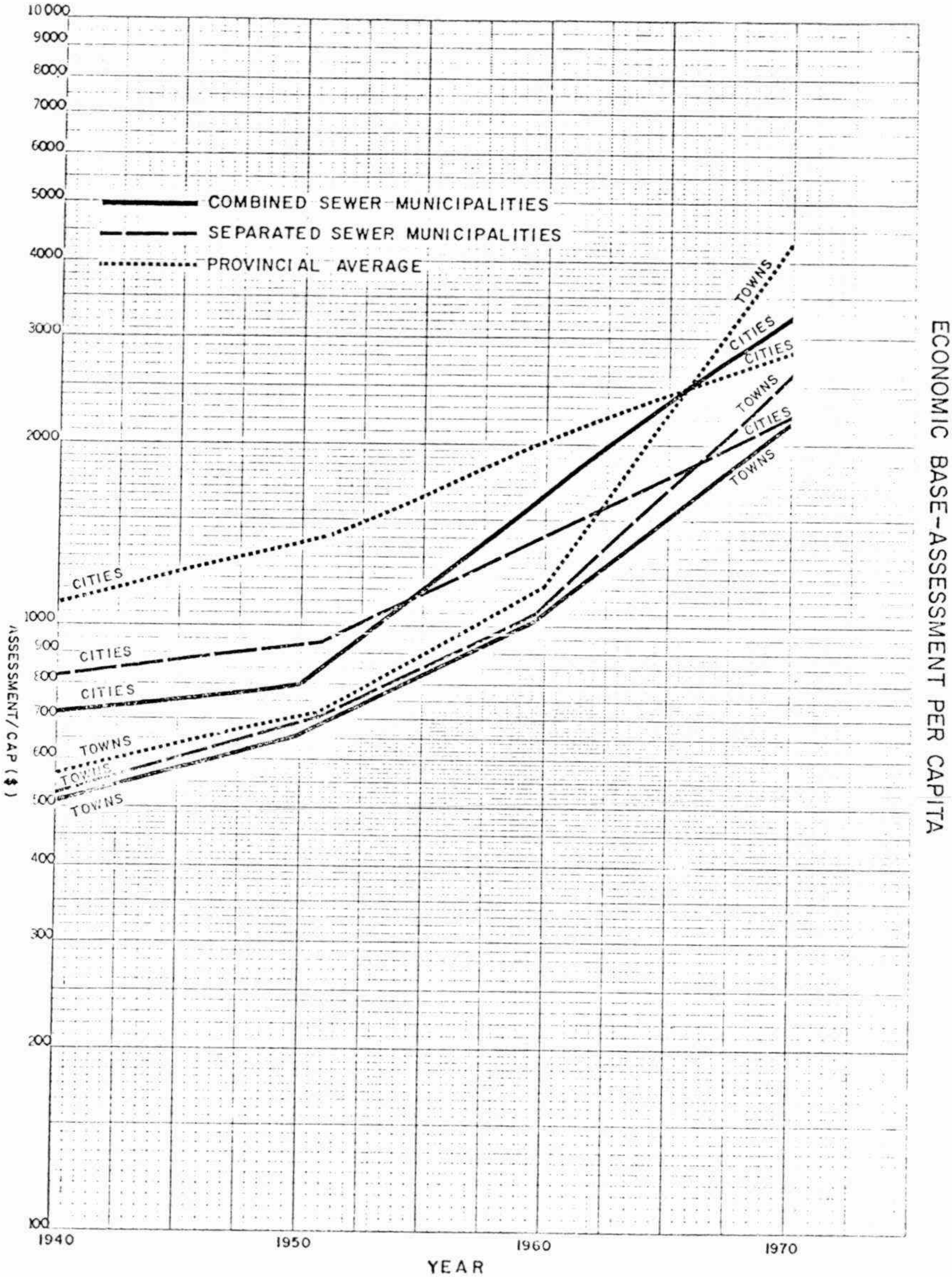


FIGURE D.2. ECONOMIC BASE - ASSESSMENT PER CAPITA

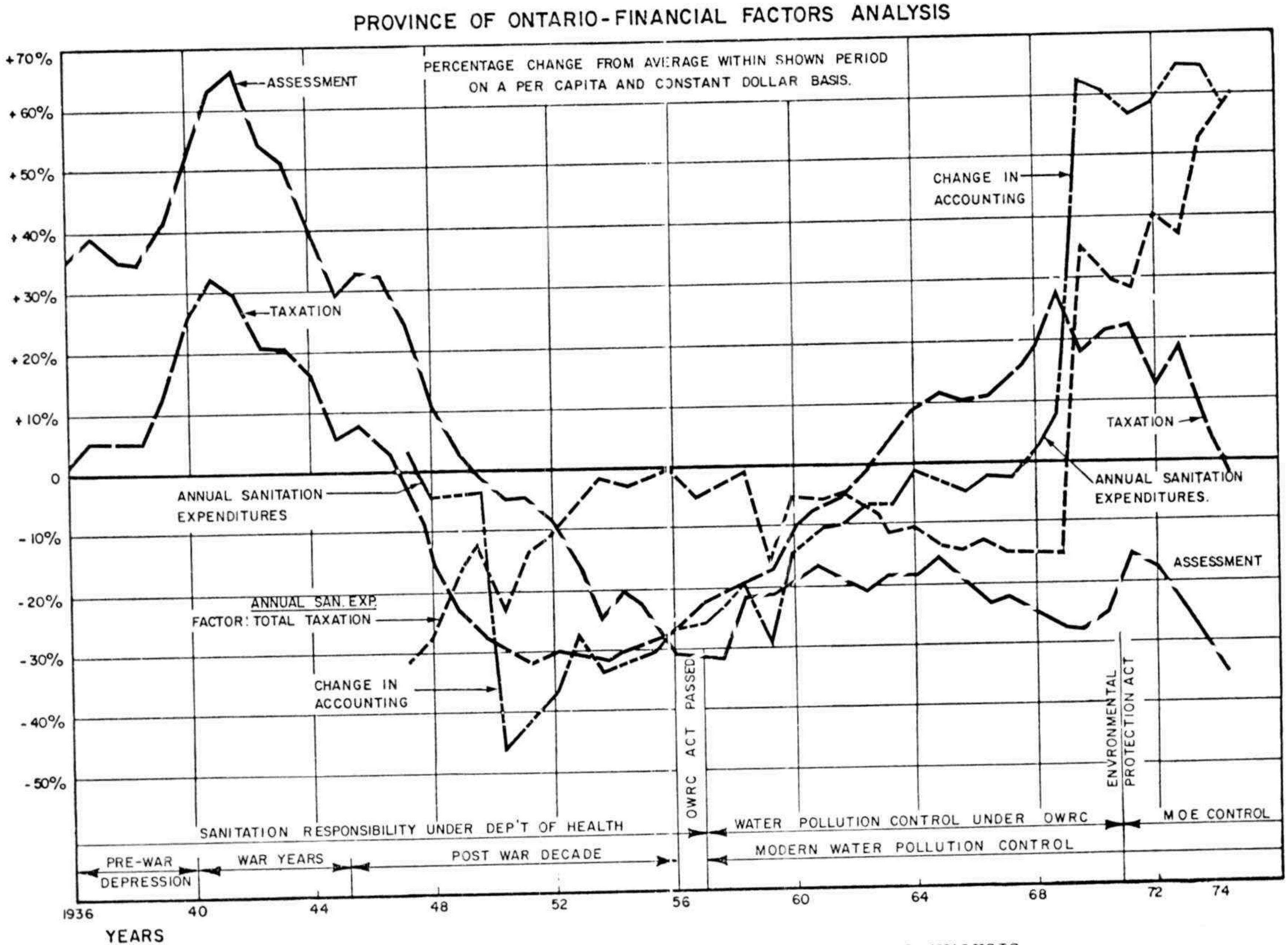
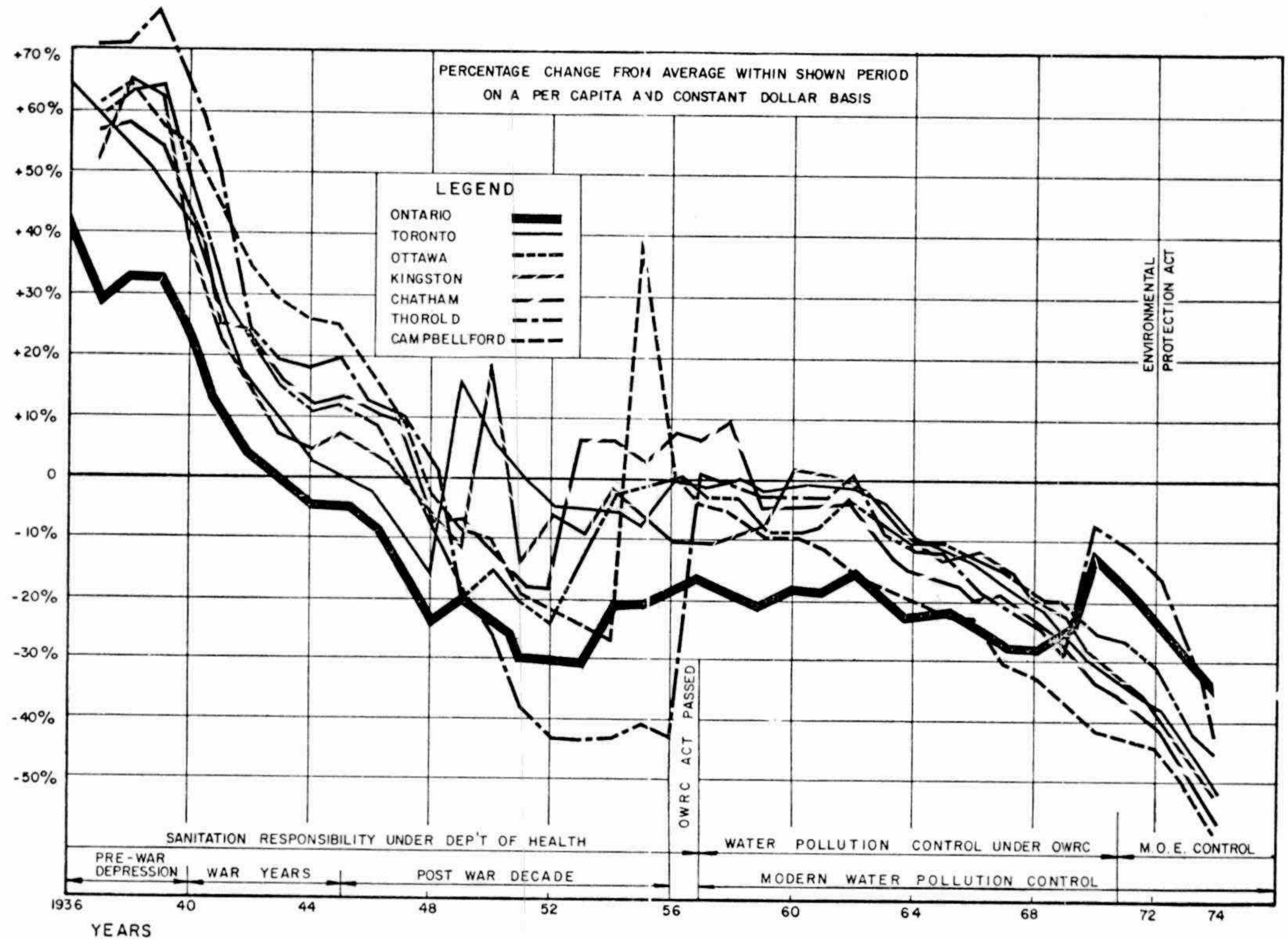


FIGURE D.3. PROVINCE OF ONTARIO - FINANCIAL FACTORS ANALYSIS



D.4. COMPARATIVE ANALYSIS OF ASSESSMENT - ONTARIO AND MUNICIPAL CASE STUDIES

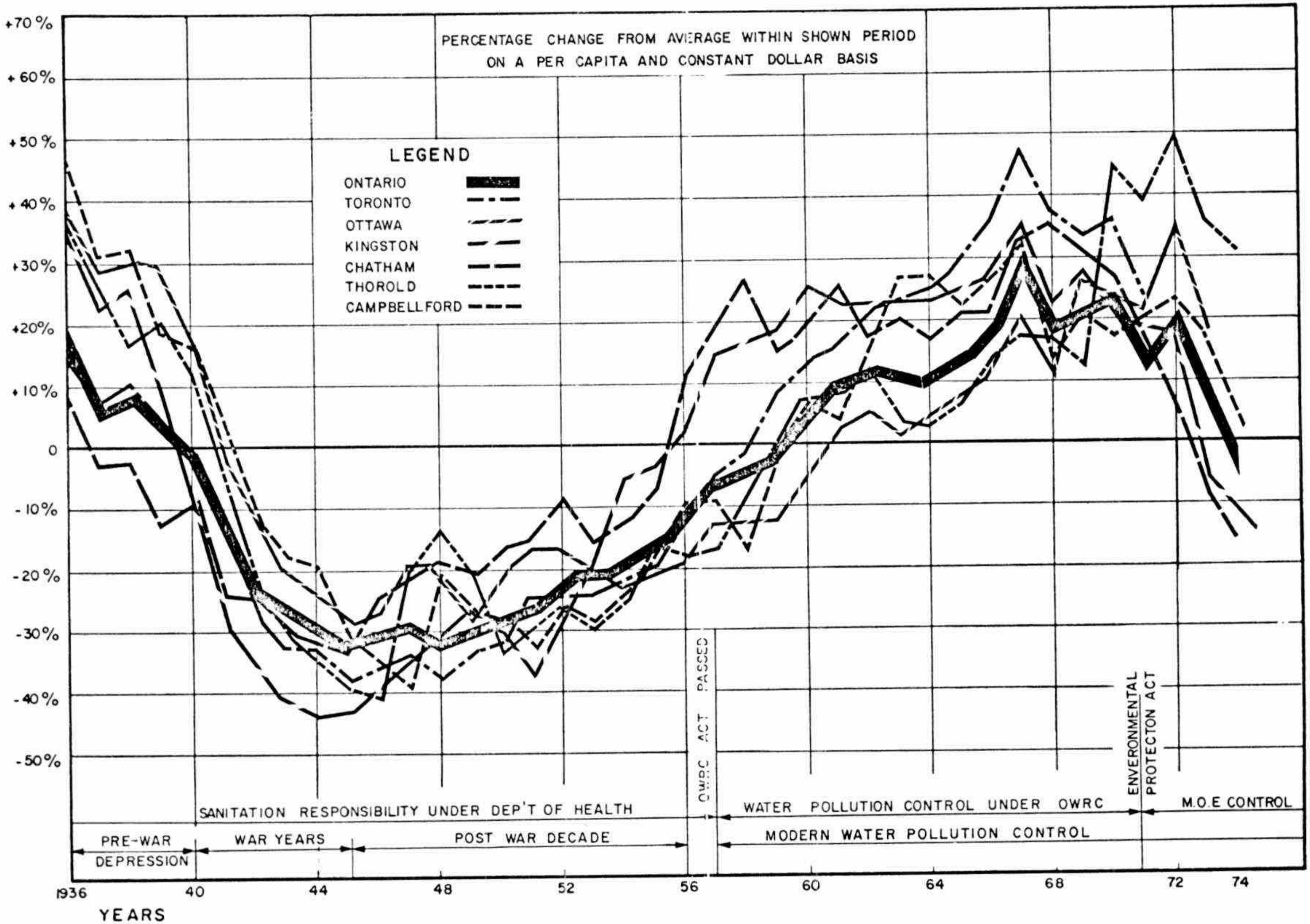


FIGURE D.5. COMPARATIVE ANALYSIS OF TAXATION - ONTARIO AND MUNICIPAL CASE STUDIES

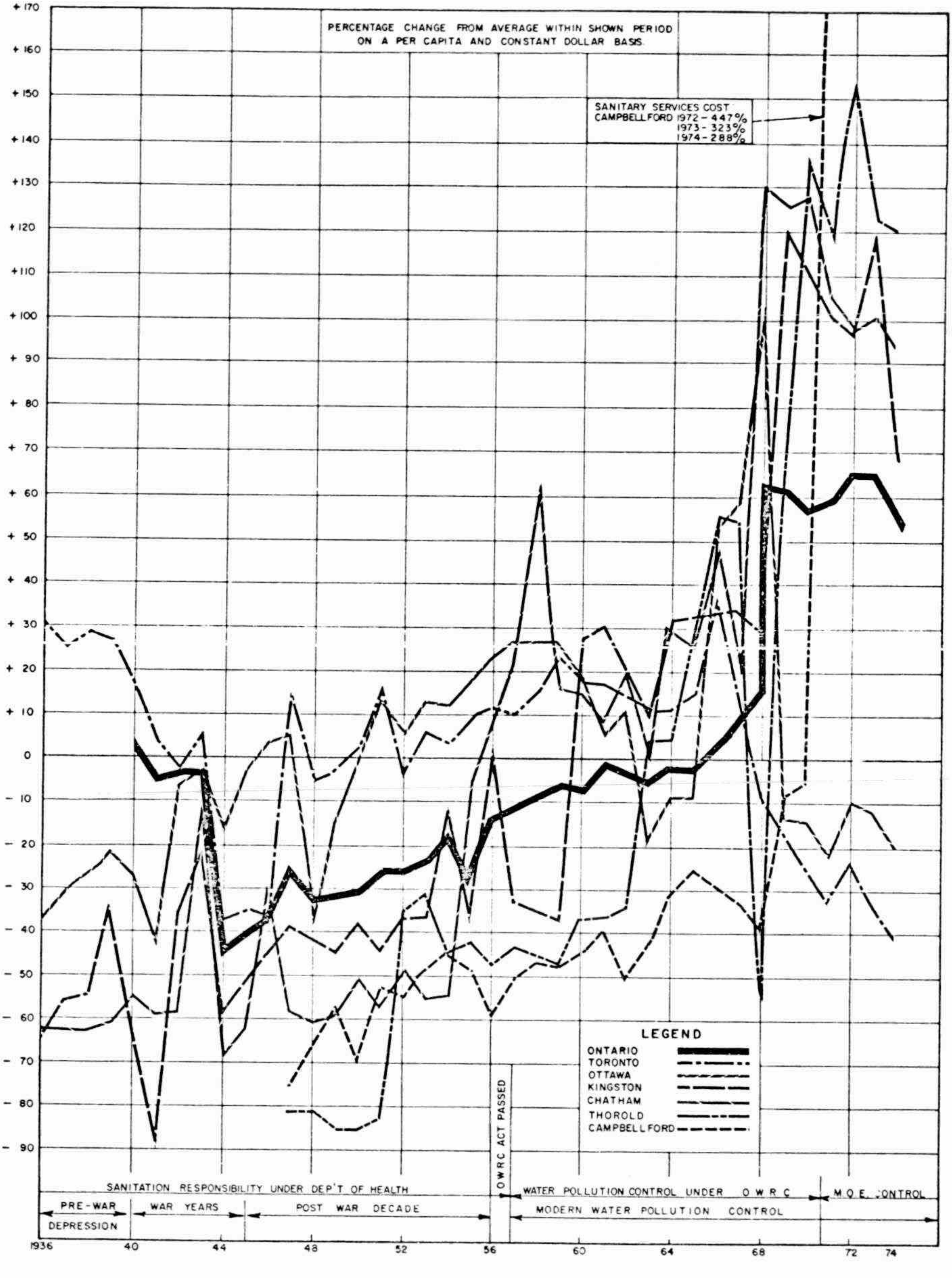


FIGURE D.6. COMPARATIVE ANALYSIS OF SANITARY SERVICES COSTS - ONTARIO AND MUNICIPAL CASE STUDIES

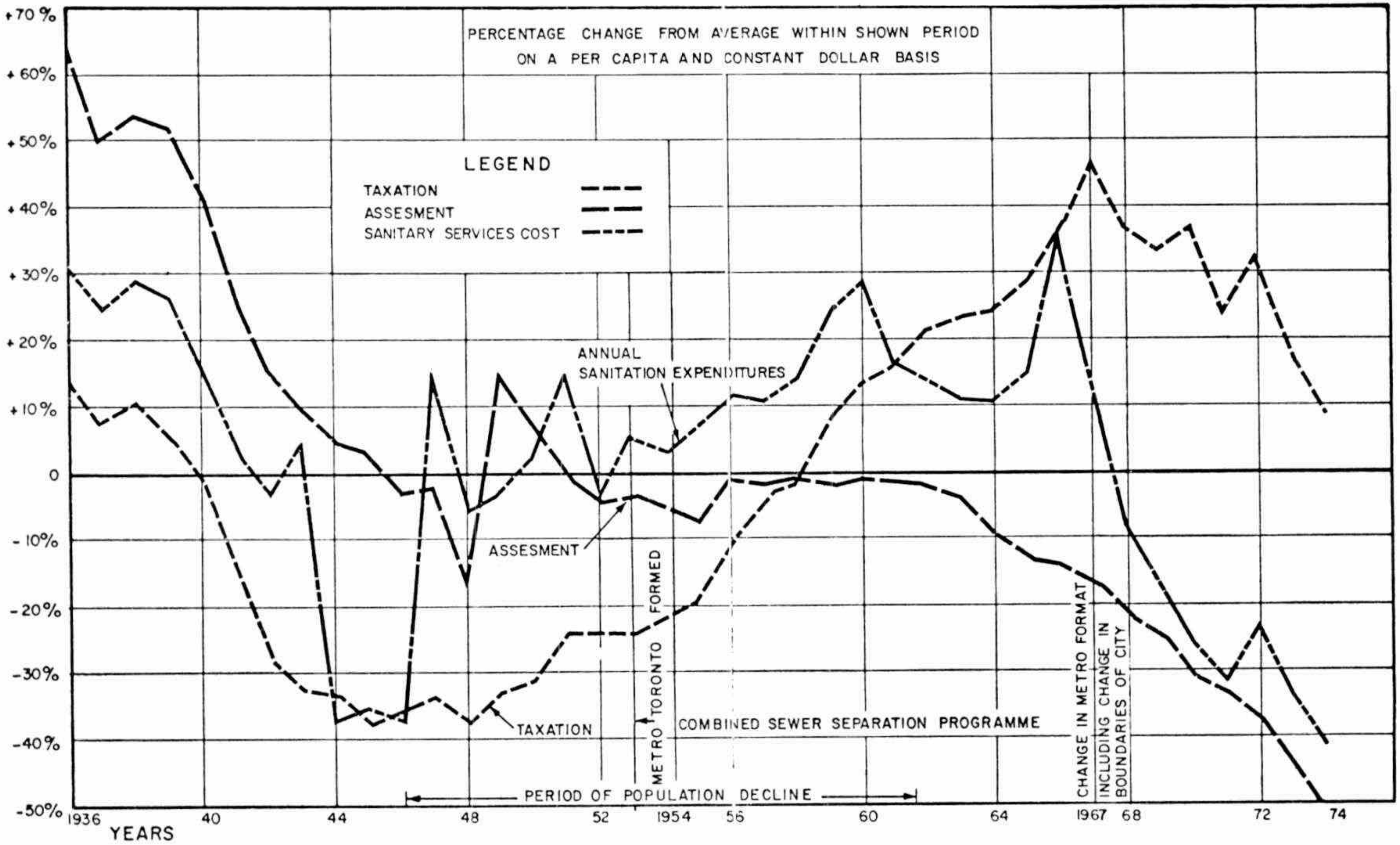


FIGURE D.7. CITY OF TORONTO - FINANCIAL FACTORS ANALYSIS

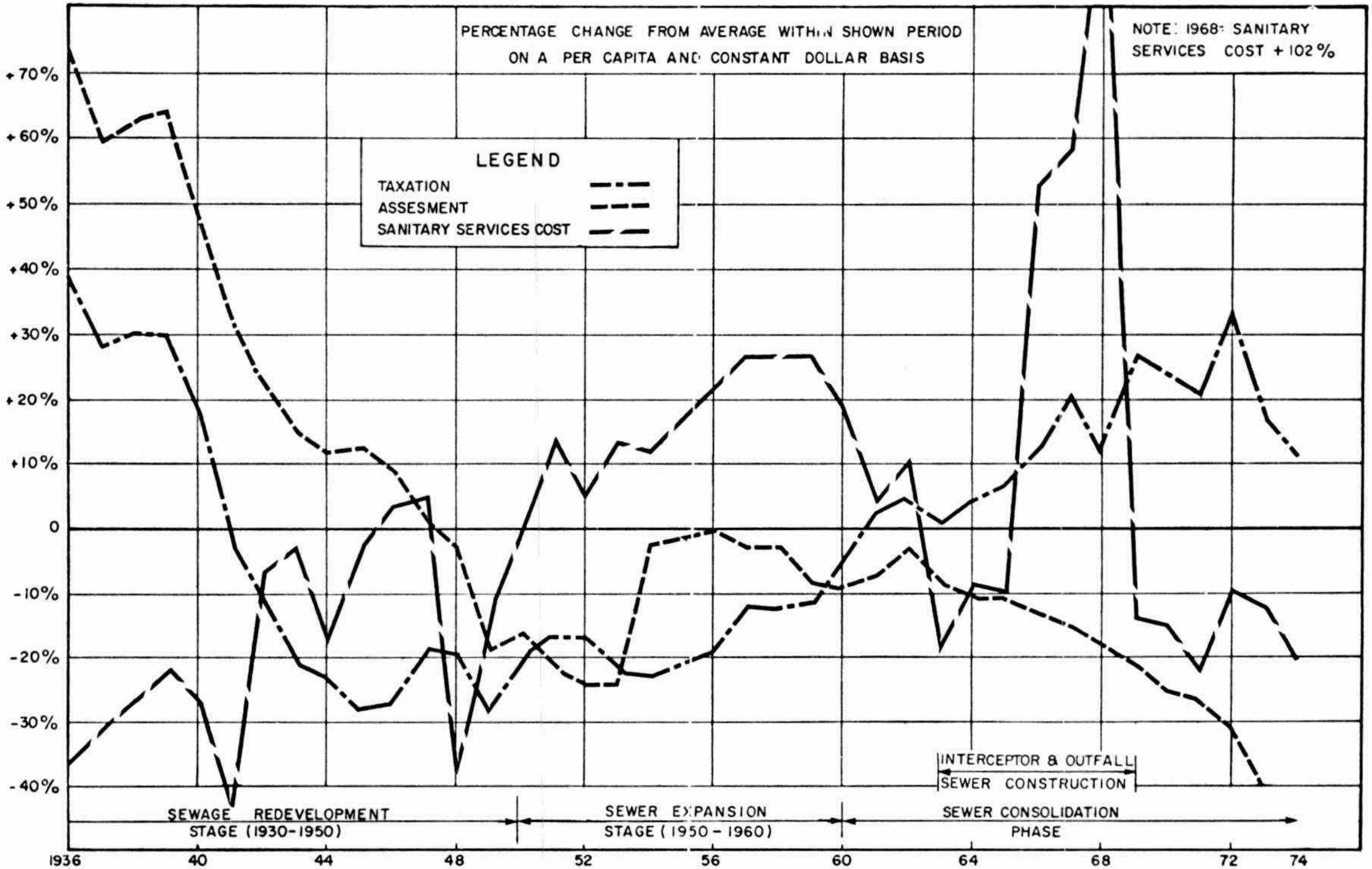


FIGURE D.8. CITY OF OTTAWA - FINANCIAL FACTORS ANALYSIS

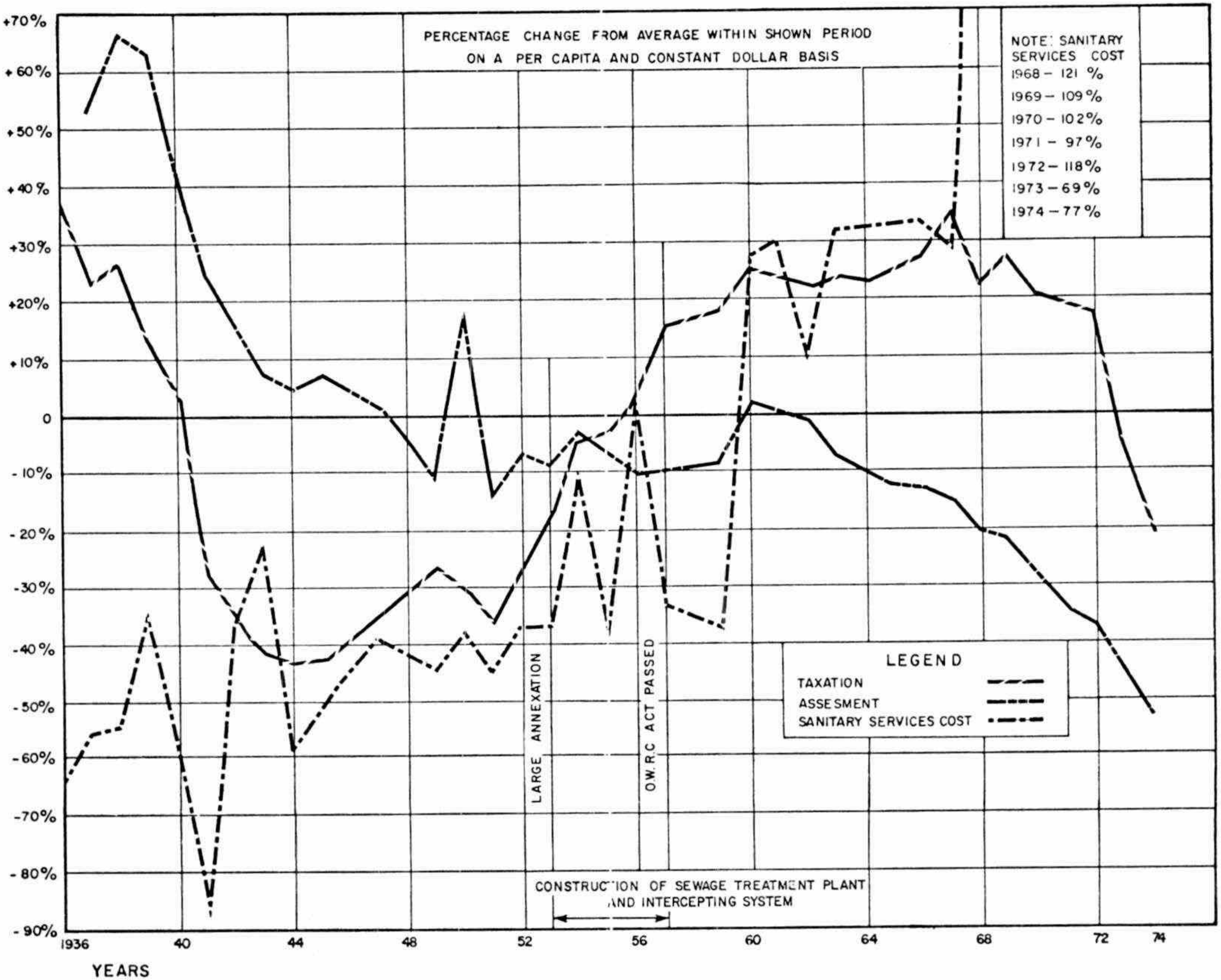


FIGURE D.9. CITY OF KINGSTON - FINANCIAL FACTORS ANALYSIS

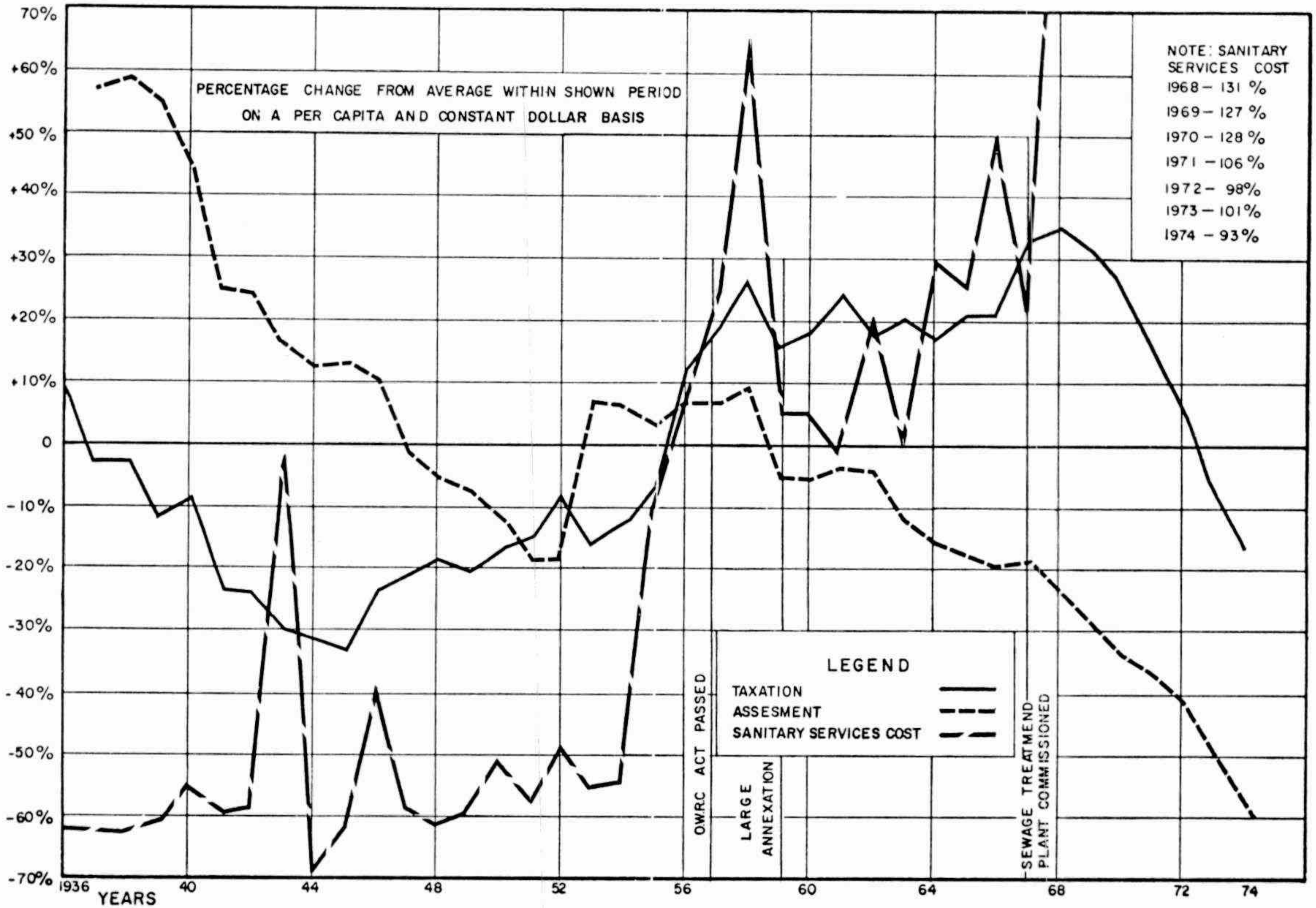


FIGURE D.10. CITY OF CHATHAM - FINANCIAL FACTORS ANALYSIS

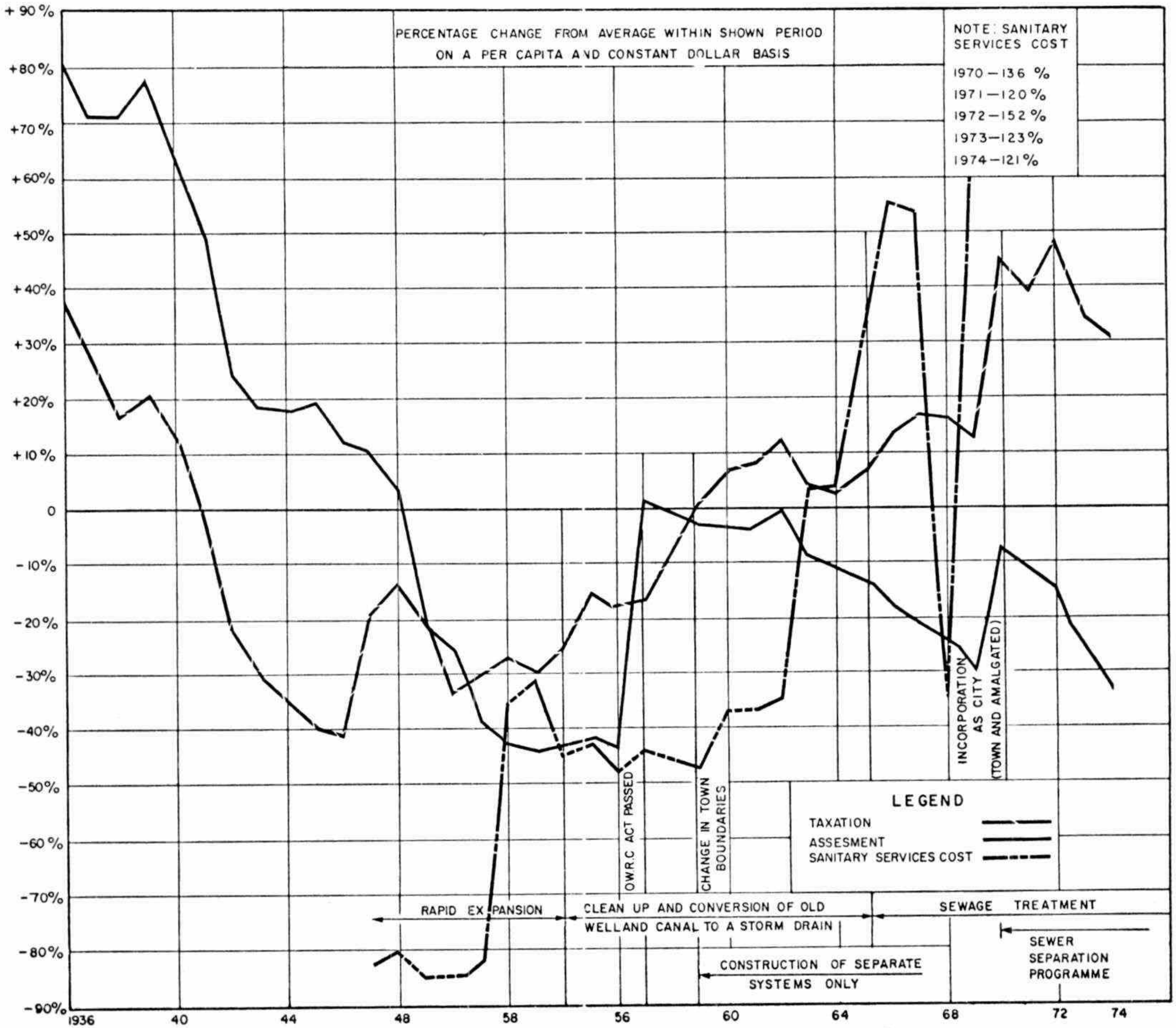


FIGURE D.11. CITY OF THOROLD - FINANCIAL FACTORS ANALYSIS

FIGURE D.12. TOWN OF CAMPBELLFORD - FINANCIAL FACTORS ANALYSIS

TABLE D.3. SUMMARY OF POPULATION DEVELOPMENT

Item	Urban Population Ranges: over 100,000	100,000-20,000	20,000-10,000	10,000-5,000	5,000-2,500	Totals
A. PRESENT PICTURE						
(1) Surveyed lower-tier municipalities	16	39	51	80	136	322
(2) Number reported to have combined sewers	9	10	11	17	16	63
(3) Percentage of municipalities reporting to have combined sewers	54.3	25.6	21.6	21.2	11.8	19.6 (Provincial Average)
(4) Percentage of 1975 population in municipalities with combined sewers as compared with total 1975 population in the same group	59.2	24.6	19.5	20.9	12.9	41.6 (Provincial Average)
B. DEVELOPMENT TRENDS IN COMPARISON						
(5) 1975 population in above Item (1) municipalities in 1,000's	4,008	1,747	703	554	490	7,502
(6) 1940 populations in above Item (2) municipalities in 1,000's	1,212	137	69	66	39	1,573
(7) Average Factor $\frac{1975}{1940}$ populations (from dividing the numbers of Item (5) by Item (6))	1.88	3.13	1.98	1.75	1.65	1.98
(8) Percentages of 1940 population in municipalities with combined sewers, relative to overall 1975 population	31.5	7.9	9.9	11.9	7.9	21

TABLE D.4. POPULATION GROWTH TRENDS

	1926-1936	1936-1941	1941-1946	1946-1951	1951-1956	1956-1961	1961-1966	1966-1971	1971-1976	1976-2001
A. Pop. > 100,000										
Toronto - From	557,530±	645,462	655,751	696,555	653,499	643,791	643,514	646,350	680,319	(681,570)
To	645,462	655,751	696,555	653,499	643,791	643,514	645,350	680,319	(681,570)	(816,600)
% Growth	+1.475	+0.317	+1.215	-1.284	-0.300	-0.009	+0.088	+1.030	+0.184	+0.726
Ottawa - From	112,200±	141,903	154,585	163,403	195,067	218,013	262,639	288,377	285,424	(306,450)
To	114,903	154,585	163,403	195,067	218,013	262,639	288,377	285,424	(306,450)	(481,500)
% Growth	+2.377	+1.727	+1.116	+3.606	+2.249	+3.795	+1.887	-0.206	+1.432	+1.824
B. Pop. > 20,000										
Kingston - From	21,633	23,513	28,345	(32,147)	41,056	45,625	48,432	54,086	59,073	(61,495)
To	23,513	28,345	(32,147)	41,056	45,625	48,432	54,086	59,073	(61,495)	(66,800)
% Growth	+0.837	+3.809	+2.549	+5.014	+2.133	+1.201	+2.233	+1.780	+0.807	+0.332
Chatham - From	13,900±	15,910	17,893	18,380	21,473	22,658	29,162	31,479	33,288	(39,024)
To	15,910	17,893	18,380	21,473	22,658	29,162	31,479	33,288	(39,024)	(48,200)
% Growth	+1.360	+2.377	+0.539	+3.160	+1.080	+5.177	+1.541	+1.124	+3.231	+0.848
C. Pop. > 10,000										
Thorold - From	3,770±	4,070	4,105	5,044	6,356	7,904	8,602	8,820	15,138(R)	(14,585)
To	4,070	4,105	5,044	6,356	7,904	8,602	8,820	15,138(R)	(14,585)	(20,100)
% Growth	+0.770	+0.171	+4.206	+4.733	+4.456	+1.707	+0.502	-0.107	-0.747	+1.291
D. Pop. < 10,000										
Campbellford - From	2,700±	2,849	2,864	2,975	3,192	3,338	3,428	3,382	(3,490)	(3,431)
To	2,849	2,864	2,975	3,192	3,338	3,428	3,382	(3,490)	(3,431)	(3,800)
% Growth	+0.540	+0.105	+0.763	+1.418	+0.898	+0.534	-0.271	+0.63 1	-0.340	+0.409
Ontario Avg. - From	2,941,437	3,377,832	3,509,341	3,694,528	.4325,503	5,130,947	5,928,372	6,632,930	7,383,278	(8,132,000±)
To	3,377,832	3,509,341	3,694,528	4,325,503	5,130,947	5,928,372	6,632,930	7,383,279	(8,132,000±)	(11,646,200)
% Growth	1.393	0.767	1.034	3,204	3.474	2.931	2.271	2.167	(1.951) 1.385	1.447

TABLE D.5. PERCENT OF ANNUAL POPULATION GROWTH

	1926-1936	1936-1941	1941-1946	1946-1951	1951-1956	1956-1961	1961-1966	1966-1971	1971-1976	"A" 1976-2000	1936-1971	"B" 1976-2000
A. Pop. > 100,000												
Toronto	+1.475	+0.317	+1.215	-1.284	-0.300	-0.009	+0.088	+1.030	+0.184	+0.726	+0.150	+1.013
Ottawa	+3.377	+1.727	+1.116	+3.606	+2.249	+3.795	+1.887	-0.206	+1.432	+1.824	+2.017	+1.554
Average	+1.926	+1.022	+1.166	+1.161	+0.975	+1.893	+0.988	+0.412	+0.808	+1.275	+1.084	+1.284
B. Pop. > 20,000												
Kingston	+0.837	+3.809	+2.549	+5.014	+2.133	+1.201	+2.233	+1.780	+0.807	+0.332	+2.667	+0.479
Chatham	+1.360	+2.377	+0.539	+3.160	+1.080	+5.177	+1.541	+1.124	+3.231	+0.848	+2.132	+0.738
Average	+1.098	+3.093	+1.544	+4.087	+1.607	+3.189	+1.887	+1.452	+2.019	+0.590	+2.400	+0.609
C. Pop. > 10,000												
Thorold	+0.770	+0.171	+4.206	+4.733	+4.456	+1.707	+0.502	-0.107	-0.747	+1.291	+2.611*	+1.106
D. Pop. < 10,000												
Campbellford	+0.540	+0.105	+0.763	+1.418	+0.898	+0.534	-0.271	+0.631	-0.340	+0.409	+0.581	-0.036
A-D Average		+1.098	+1.920	+2.850	+1.984	+1.831	+0.777	+0.597	+0.435	+0.891	+1.669	+0.741
Ontario Average	+1.393	+0.767+	+1.034	+3.204	+3.474	+2.931	+2.271	+2.167	+1.385	+1.447	+2.259	+1.447
Difference with Ontario Average Growth												
Toronto	+0.082	-0.450	+0.181	-1.920	-3.714	-2.940	-2.183	-1.137	-1.201	-0.721	-2.109	-0.434
Ottawa	+0.984	+0.960	+0.082	+0.402	-1.225	+0.664	-0.384	-2.373	+0.047	+0.377	-0.242	+0.107
Kingston	-0.556	+3.042	+1.515	+1.810	-1.341	-1.730	-0.038	-0.387	-0.578	-1.115	+0.408	-0.968
Chatham	-0.033	+1.610	-0.495	-0.044	-2.394	+2.246	-0.730	-1.043	+1.846	-0.599	-0.127	-0.709
Thorold	-0.623	-0.596	+3.172	+1.529	+0.982	-1.224	-1.769	-2.060	-2.132	-0.156	+0.352	-0.341
Campbellford	-0.853	-0.662	-0.271	-1.786	-2.576	-2.397	-2.000	-1.536	-1.045	-1.038	-1.678	-1.483
A-D Average	-0.167	+0.331	+0.886	-0.354	-1.490	-1.100	-1.494	-1.570	-0.950	-0.556	-0.590	-0.706
"A" - Average	+0.533	+0.255	+0.132	-1.543	-2.499	-1.038	-1.283	-1.755	-0.577	-0.172	-1.175	-0.163
"B" - Average	-0.295	+2.326	+0.510	+0.883	-1.867	+0.258	-0.384	-0.715	+0.634	-0.857	+0.141	-0.838

* 1936-1966

Note: A number of 1926-1936 and 1971-1976 growth percentages are approximations therefore, "A" (low) and "B" (high) projections are compared with the 1936-1971 overall growth rates instead.

APPENDIX E

REPORTS REVIEWED

APPENDIX E

REPORTS REVIEWED

Survey No.		
25	-	City of Brockville, Final Report on Sewer Separation, Gore and Storrie Limited, 1973.
30	-	Town of Campbellford, Influence of Subdivision Development and Storm Sewer Construction on Sewage Flows, Canadian British Engineering Consultants (1971) Limited.
35	-	City of Chatham, Report on the Storm Sewerage System, Gore and Storrie Limited, 1974.
35	-	City of Chatham, Report on Storm Sewerage System, Gore and Storrie Limited, 1976.
42	-	Town of Collingwood, Storm Sewer Study Report, Ainley and Associates Limited, 1972.
55	-	Borough of East York, Separation of the Sewer System in the Leaside Area, James F. MacLaren Limited, 1970.
55	-	Borough of East York, Report on Municipal Services in the Leaside Area, Gore and Storrie Limited, 1973.
105	-	Town of Kingsville, Sewer Separation Study, LaFontaine, Cowie, Burratto and Associates Limited, 1975.
108	-	Town of Leamington, Infiltration and Sewer Separation Study, LaFontaine, Cowie, Burratto and Associates Limited, 1975.
109	-	Town of Lincoln, Report on Sanitary Wastewater Flows, Proctor and Redfern Group, 1976.
112	-	City of London, Report on the Existing and Proposed Sewers in the Carling Creek Watershed, James F. MacLaren Ltd., 1972.
130	-	Town of Napanee, Report on Sewer System, J.D. Lee Engineering Limited, 1976.
136	-	Town of Niagara-on-the-Lake, Sanitary Sewer Separation and Storm Drainage Study, Proctor and Redfern Group, 1974.
137	-	Regional Municipality of Niagara, Servicing Master Plan, R.V. Anderson Associates Limited and Proctor and Redfern Group, 1971.

Survey No.		
153	-	City of Ottawa, Sewer Policy Report and Master Plan, Gore and Storrie Limited and Proctor and Redfern Group, 1973.
155	-	Ontario Water Resources Commission, Report on City of Owen Sound Sewage System, Gore and Storrie Limited, 1970.
161	-	Town of Penetanguishene, Final report - Storm Drainage Study, Ainley and Associates Limited, 1974.
161	-	Town of Penetanguishene, Interim Report, South-East Area, Ainley and Associates Limited, 1974.
184	-	City of St. Thomas, Storm Relief and Development of Sewerage and Drainage Systems, James F. MacLaren Limited, 1968.
186	-	Township of Sandwich West, Report on Storm Water Drainage, LaFontaine, Cowie, Burratto and Associates Limited, 1975.
187	-	City of Sarnia, Report on Central City Sewerage and Drainage Improvements, James F. Maclaren Limited, 1969.
189	-	City of Sault Ste. Marie, Extraneous Flow Study - Clark Creek and Tarentorus 1 Drainage Areas, Proctor and Redfern Group, 1967.
197	-	Separated Town of Smiths Falls, Report on Smiths Falls Sewers and Sewage Plant, J.D. Lee Engineering Limited, 1967.
208	-	City of Thorold, Extraneous Flow Study, Proctor and Redfern Group, 1974.
208	-	City of Thorold, Analysis and Report on Sanitary Sewage Monitoring Program, Proctor and Redfern Group, 1975.
209	-	City of Thunder Bay, Water Pollution Control Study (Fort William Sector), W.L. Wardrop and Associates Limited, 1970.
215	-	City of Toronto, Explanatory Report on Analysis of Hydrograph-Volume Method and Supplementary Report No. 1 - North Toronto Sewer System, Dorsch Consult Limited, 1972.
215	-	City of Toronto, Explanatory Report on Analysis by Hydrograph-Volume Method - West Toronto Sewer System, Dorsch Consult Limited, 1974.
215	-	City of Toronto, Sewer System - Progress Report #1, R.M. Bremner, Commissioner of Public Works.
215	-	University of Toronto, St. George Campus - Report on Separation of Storm and Sanitary Flows, James F. MacLaren Limited 1971.

Survey No.		
226	-	Town of Wallaceburg, Report on Sanitary Sewer System Infiltration Study, Gore and Storrie Limited, 1975.
240	-	City of Woodstock, Master Plan for Sewage and Drainage Works, James F. MacLaren Limited, 1974.
243	-	Borough of York, Central Area Sewer System, Gore and Storrie Limited, 1968.
243	-	Borough of York, Report on the Western Area Sewer System, Gore and Storrie Limited, 1967.

APPENDIX F

CASE HISTORIES

APPENDIX F

CASE HISTORIES

This appendix is presented in three parts:

F.1 - Case Histories of Municipalities over 100,000 - cities of Toronto and Ottawa

F.2 - Case Histories of Municipalities over 20,000 - Kingston and Chatham

F.3 - Case Histories of Municipalities under 20,000 - Thorold and Campbellford.

The contents of each of the three parts is as follows:

F.3.3 City of Thorold Sewer Systems and Problems

F.3.4 Town of Campbellford Sewer Systems and Problems

F.1 CASE HISTORIES OF MUNICIPALITIES OVER 100,000 - CITIES OF TORONTO AND OTTAWA

In the summaries of the collected case history information presented in this section, a side-by-side review, where practicable, is given to allow comparisons between municipalities in the same size categories.

Certain other information of interest for this study and which may be unique for a given municipality, of course, is presented individually.

F.1.2 Historical information on municipal and sewer development

Table F.1 presents an historical overview as background information for the City of Toronto and City of Ottawa.

Figure F.2 demonstrates the relatively large expansion of Ottawa's sewer system in the last 25 years. The need for sewage treatment in Ottawa, with its receiving waters consisting mainly of rivers and creeks, came much later than in Toronto which has Lake Ontario as its main receiving water body. Sewer development in Toronto also was considerably more gradual. Consequently, Toronto has a higher percentage of combined sewers than has Ottawa; about 57 percent of total sewer length in Toronto and 22 percent in Ottawa, at present. The length of overall sewer systems on a per capita basis is appreciably lower in Toronto than in Ottawa, because of the latter's extent of combined sewers (8.36 ft/capita in Toronto; 15.52 ft/capita in Ottawa).

Moreover, with respect to the area within the present municipal boundaries, Toronto is practically filled up, while Ottawa has still considerable room for growth. The City of Toronto's overall population density at present is about 28.5 persons per acre as compared to 11.1 persons per acre in the City of Ottawa. This overall density difference is even higher when compared on a regional basis, because Metro Toronto's density is about 13.8 persons per acre and the Region of Ottawa-Carleton's density is about 0.75 persons per acre.

TABLE F.1. TORONTO AND OTTAWA - HISTORY SUMMARY

CITY OF TORONTO		CITY OF OTTAWA	
Year	Events	Year	Events
1793	Town of York laid out by Queen's Rangers.	1826	First settler in City area, then Township of Nepean. Start of construction of Rideau Canal under Colonel John By. Settlement grows around military barracks built on Parliament Hill site.
1796	Upper Canada Legislative Assembly moved to Town of York.		
1834	Incorporation of the City of Toronto comprising 5,737 acres with a population of 9,254 (1.6 persons/acre).	1847	Settlement with population of 5,000 incorporated as "Bytown".
1834-1891	Many brick sewers build to replace wooden box culverts.	1855	Bytown, grown to population of 8,000 is incorporated as the City of Ottawa.
1843	First water works installed.		
1870	Tile sewers introduced (made in Scotland).	1857	Ottawa becomes the capital of Upper and Lower Canada.
1883	With population grown to 86,585, first Medical Officer of Health appointed by City.	1859	Construction of Parliament Buildings started.
		1867	Dominion of Canada proclaimed with Ottawa as its capital. The City's population then has grown to 19,000.
1891	Initiation of actions to overcome pollution of Lake Ontario contaminating the City's water supply; brick and tile combined sewer system now extending 216 miles with population of 170,651 (which is equal to 6.7 linear ft/capita).	1872	Queen Street water works and pumping station built.
		1874	Main improvement of combined sewers by construction of "the Main Drain".
1883-1912	29 annexations in this period increase the original City area 3 times to 17,131 acres. The 1912 population has grown to 410,036 or nearly 5-fold in this 30 years.	1877	Completion of this trunk to the Ottawa River.
		1874-1930	Sewer development phase - see Figure F.1. In these years, the City expanded with numerous annexations and the main framework of combined collector sewers serving the expanded City was completed by 1920.
1904	Great downtown fire triggers upgrading of municipal systems including new high pressure water system downtown.		

TABLE F.1. (CONT'D)

CITY OF TORONTO		CITY OF OTTAWA	
Year	Events	Year	Events
1909 - 1913	Construction of high and low level interceptors together with sedimentation tanks at Ashbridges Bay.	1907	Ottawa East annexed into City.
1926 - 1929	North Toronto S.T.P. constructed to serve developed areas; total City area then 17,162 acres with population over 550,000 (about same population density as in 1976).	1930 - 1950	Sewer redevelopment phase started because of high incidence of surcharging and floodings and sewer explosions in 1929, 1930 and 1931.
1954	Formation of Metropolitan Corporation, which assumes responsibility for trunks, interceptors, pumping stations and plants. Population grown more slowly to 665,000 in 1953 with an annexation jump in 1954 to 682,425, but building density appreciably increased downtown.	1931	Works Department Sewer Complaints Bureau initiated; City Hall fire destroys sewer records.
1953	Combined sewer separation program started.	1949	Green Creek S.T.P. proposed.
1960	Program of relief to the Garrison Creek area started.	1950 - 1960	Sewer expansion phase, following annexation of large portions of the Townships of Nepean and Gloucester with population of 18,000.
1967	Metro's 13 municipalities consolidate to the City and 5 Boroughs. Annexation of Forest Hill and Swansea increases City area to 24,006 acres. Population in 1966 of 646,300 increases in 1967 to 667,571. Sewer system grown to 780 miles.	1961 - present	Sewerage consolidation phase, including major collector and interceptor works.
1976	Population grown to about 681,600.	1963 - 1968	Construction of Ottawa interceptor and outfall sewer, Green Creek collector sewer and Green Creek Pollution Control Centre.
		1969	Establishment of Regional Municipality of Ottawa-Carleton. The Region assumes the responsibility for all major sewers, trunks, collectors and the treatment facilities.
		1973	Master Sewer Plan adopted. Total sewer system in the City grown to 853 miles, of which 53 miles of major collectors are the Regions's responsibility.
		1976	Population grown to about 306,500.

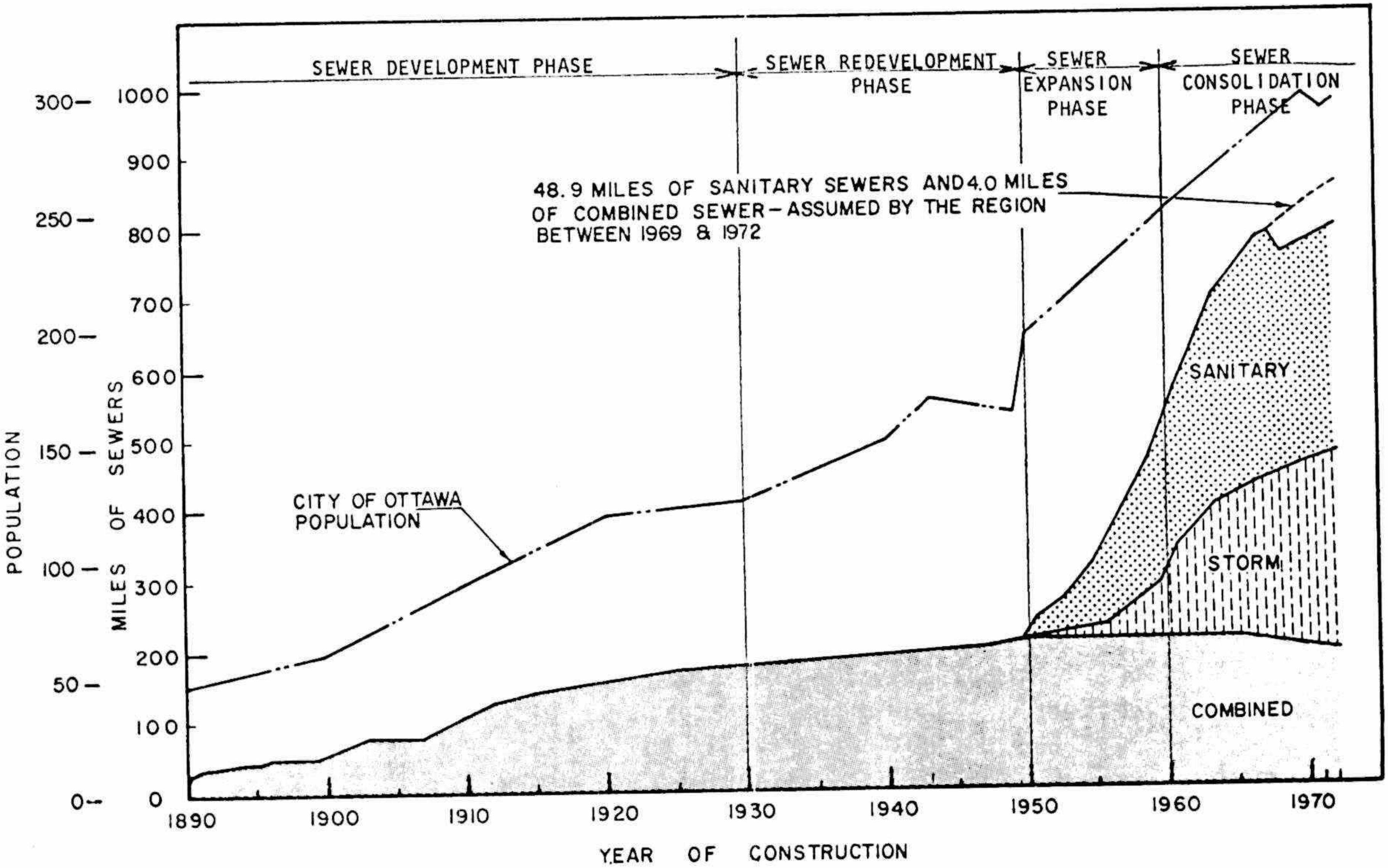


FIGURE F.1. GROWTH OF SEWER SYSTEM AND POPULATION, CITY OF OTTAWA

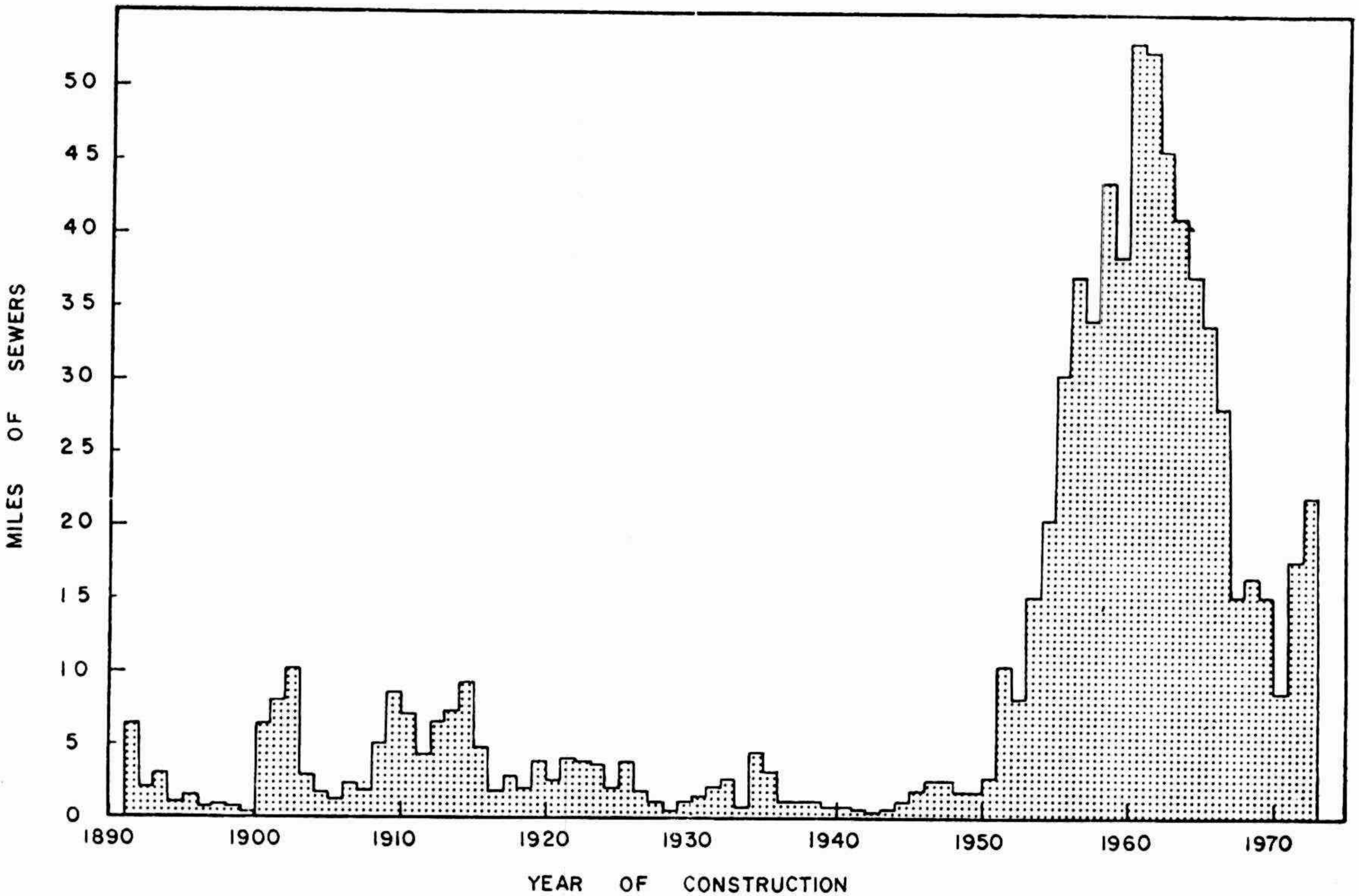


FIGURE F.2. MILEAGES OF SEWERS CONSTRUCTED EACH YEAR, CITY OF OTTAWA

As will be appreciated, these differences in development characteristics and general planning considerably affect sewer development and dealing with combined sewer problems. As case histories in the municipal size "Group A" with population over 10,000, the sewer problems and development work of Toronto and Ottawa, therefore, tend to be quite different from other municipalities.

For instance, in general, Ottawa's topography is flatter than Toronto's, the number of flooding complaints in Toronto in recent years average about 30 per 100 acres per year as compared to about 2.5 per 100 acres per year in Ottawa, or on a population number basis, 12.1 per year per 1000 persons in Toronto and 1.4 per year per 1000 persons in Ottawa.

With respect to pollution control, Toronto started sewage treatment more than 60 years ago, while in Ottawa the Green Creek Pollution Control Centre is only eight years old. In both locations the sanitary trunk collectors and interceptors and the water pollution control plants (Table F.2) are under the jurisdiction of the Metropolitan and Regional municipalities, respectively.

F.1.3 Financial factors

In Appendix D, graphs are presented for the Cities of Toronto and Ottawa showing a financial factors analysis for these two cities, on the same basis as presented in Appendix D, Figure D.3, for the Province as a whole. Historical events relevant to sewer development in each case are noted on the individual graphs to show the relationship, if any, between development events and expenditures.

Table F.3 shows percentage variations found in comparison with the provincial average over 40 years of records.

The above percentages and their variations appear to be generally about the same for both cities. Ottawa's annual and capital sanitary expenditures would appear to be somewhat higher than Toronto's on the basis of a percentage of general taxation but, in turn, taxation in Ottawa is somewhat lower relative to assessment, so that in overall aspect the financial basis is very similar. The graphs for both cities, although showing a similar pattern, in general, differ to the extent that Ottawa shows more pronounced fluctuations especially with respect to the

TABLE F.2. TREATMENT FACILITIES AT TORONTO AND OTTAWA

	Metropolitan Toronto	Ottawa-Carleton Region
1975 average daily flow in mgd at all regional WPCP's	274.2	70.0
Percent of nominal capacity	83	80
Approximate 1975 population served	2,160,000	428,200
Total 1975 assessed population in the regional areas	2,152,269	506,592
Approximate population percentage served by WPCP's	100	85
Approximate per capita flow in 1975 - average for the Region (gpcd)	127	163
Approximate per capita flow in 1975 for main WPCP's only (gpcd)	Ashbridges Bay 136	Green Creek 170

TABLE F.3. TORONTO-OTTAWA - FINANCIAL FACTORS

	City of Toronto	City of Ottawa	Ontario Average
(a) Average Percentage of <u>annual</u> sanitation expenditures relative to overall municipal taxation	6.8	7.1	6.9
Maximum variation in above percentages during period of records	3.4 to 10.9	3.1 to 12.2	5.1 to 10.5
(b) Average percentage of <u>capital</u> expenditures for sanitation relative to overall municipal taxation	2.2	3.5	6.0
Maximum variation in above percentages during period of records	0.4 to 9.5	0.3 to 19.2	0.9 to 20.7
(d) Taxation as a percentage of assessment - average for period	6.0	5.7	5.5
Variations in period (see also Ontario graph)	3.2 to 12.4	3.4 to 10.9	3.5 to 8.5

annual expenditures. This appears to be correlated with municipal size. The smaller the municipality the larger the relative fluctuations over the years.

F.1.4 Description of Sewer Systems and their Development

F.1.4.1 City of Toronto sewer systems

The City area has a natural slope towards the Lake. Compared to mean water level of Lake Ontario of elevation 246, the central portion of the city averages elevation 400 and the highest point is at elevation 608. The original natural drainage consisted of two principal river systems, the Don River on the east and the Humber River on the west, with a large number of creeks in between. Except for the creeks through parklands, most original creek channels have been enclosed and filled. All principal combined trunk sewers flow from north to south towards the Lake. Furthermore, a large area drains to the Don River and a very small area to the Humber River. Prior to 1908, the City's sewers discharged directly into the harbour and lakefront.

The original city area in 1834, from the waterfront to Bloor Street on the north, the Don River on the east and Dufferin Street in the west, is entirely served by combined sewers. A public outcry in 1891 on the unsightly appearance of the Bay and the associated stench triggered a consulting engineers report recommending the construction of the high and low level interceptors. The annexations between 1883 and 1900, causing piecemeal incorporation of township and district sewerage systems, complicated the situation and subsequently Ashbridges Bay instead of Victoria Park was selected as the main outlet point with sedimentation tanks to remove the heavier solids. Because of the citizens' opposition in this area, implementation was delayed until 1909.

Between 1909 and 1913 two sanitary trunk interceptors, known as the High Level and Low level Interceptor Sewers, were constructed to convey sanitary flows to the Ashbridges Bay tanks. This system includes four pumping stations to serve low lying areas. There are 18 major overflow outlets spaced along the lakeshore and harbour and, in addition, nine outlets to the Don River and one outlet to the Humber River.

The limited capacities of the combined and semi-combined sewer systems in the City required construction of relief sewers together with numerous diversion structures in the existing sewers. There are at present over 500 such diversion structures in operation on the City's sewer system.

Furthermore, there are a number of areas in the adjacent Boroughs connected to the City's systems, of which the largest contribution is provided from 2,500 acres in the Borough of North York.

A 1965 inventory of the City's existing system shows a percentage breakdown in type of sewer construction as follows:

Brick sewers	20%
Vitrified clay sewers	71%
Concrete sewers	9%

With respect to system age, a 1970 inventory of all sewers in the City provided the following breakdown percentages:

Prior to 1900	22%
Between 1901 and 1926	36%
Between 1926 and 1968	42%

Between 1953 and 1960 a program of sewer separation in selected City areas was undertaken. The 1960 report by the Commissioner of Public Works, R.M. Bremner, P.Eng., reviewed the state of the City's systems and proposed a comprehensive program of rehabilitation and upgrading along the following specific lines:

1) A rehabilitation program for the older sewers in the City which have adequate hydraulic capacity but which are presently in a state of structural disrepair.
2) A program of construction of new sewers to eliminate existing flooding conditions.
3) A program of construction of new sewers to accommodate the continued development and growth of the City and to meet the demands of changing land uses.
4) A general construction program must be conceived and carried out in such a manner as to ensure that pollution of the

lakefront is kept to minimum practical limits, thereby ensuring that the highly desirable recreational facilities of the lakefront are protected.

The 25-year staged program of sewer replenishment was estimated (1965 dollars) at $154,221,000 or to average about $6.2 million dollars per year.

The design policy on which the program is based, as presented in both the 1965 and 1970 reports, is of interest because it defines, in addition to sanitary, storm and combined sewers, other "in between" types, adopted in the sewer separation program as a pragmatic approach to the City of Toronto's combined sewer problems.

F.1.4.2 City of Ottawa sewer systems

The Ottawa River, as the ultimate receiving water for all wastewater flows from the City and surrounding region, falls from about elevation 175 at Britannia Bay to about elevation 130 below the Chaudiere Falls.

Some 75 drainage areas, identified in the City's 1971 report, discharge directly to the Ottawa River or indirectly via the Rideau River, Rideau Canal or Green Creek as the main water courses and a number of smaller tributary streams. In each of these watersheds a number of drainage areas developed from original systems which were annexed later into the City and incorporated in the overall City system.

The land in the western part of the City rises away from the Ottawa River in gentle undulations to the height of land marking the Rideau River watershed at elevations varying from 270 to 330. A low-lying valley from Dow's Lake to Nepean Bay separates the western area from Parliament Hill. The Rideau River Valley is narrow and well defined through the City and east of the mouth of this river the land rises abruptly from the Ottawa River to a height of land at elevation 350, approximately one mile south of the Ottawa River. From this point southerly the land slopes gently south-east to Green Creek. This creek discharges to the Ottawa River about 2½ miles east of the city.

Most of the combined sewers are located within an area encompassed by the City boundaries as they existed in 1949. Most of these combined sewers were constructed prior to 1940 with many dating back before 1900. Table 10, Section 4.4, shows that 22 percent of Ottawa's sewers are combined sewers. This combined system in the city core area has 16 overflow points of which nine are to the Ottawa River and seven are to the Rideau River. Outside this area there are five more combined overflows to the Ottawa River.

With the construction in 1963 of the Green Creek WPCC and Interceptor Sewer, interceptor regulators were constructed at seven points to provide interception of 2½ times the dry weather flow. Collecting sewers along the Ottawa River waterfront, through the Rideau River valley area and along the south side of the city and the Green Creek valley reach this plant from the west and south. This interception did a great deal to reduce the pollutional load discharged to both the Rideau and Ottawa Rivers.

Three studies were initiated in 1965, each covering designated areas of the City. They all recommended a program of sewer separation in which construction of new storm sewers afforded utilization of existing sewers as sanitary sewers where feasible. The 1973 Sewer Policy Report and Master Plan complemented these three studies with similar proposals for the balance of the present City's drainage areas.

In general, with many existing pipes over 60 years old, it is found in the experience so far that their structural condition is unsuitable for the construction of adjacent new storm sewers, so that possibly up to 75 percent of these existing sewers must be replaced. Studies of this nature are still ongoing to determine whether separation should be by constructing new storm sewers only or by outright new construction of both separate sanitary and storm sewers.

The City's Master Plan in 1973 was estimated to have a total gross cost of $137.4 million. The City's cost, considering various subsidies and contributions, may net about $104 million and with budgeting about $5 million per year on the average for the capital works sewer program, these considered capital works may take about 21 years to complete.

From the information on the five-year budgeting for the period 1977-1981, it appears that, on the average during these five years, the capital spending on sewer works may be in the following proportion:

TABLE F.4. OTTAWA-PROPOSED FIVE-YEAR BUDGETING

Sewer separation contracts	43%
Sewer upgrading and relief sewer contracts	29%
New sewer works contracts	7%
Storm water treatment works	2%
Sewer works for new city roads	3%
Sewer works for regional road construction	16%
Total sewer works budget	100%

Thus more than 70 percent of the coming sewer work budgets will be expended on sewer separation, sewer upgrading and relief sewer construction.

F.1.5 Incidence of Flooding

The attempt to assemble comparative statistical information on flooding, particularly of basement flooding, has rendered very limited results. Ottawa has kept detailed records since the initiation in 1931 of its Works Department Sewer Complaints Bureau.

Toronto keeps year-by-year records, but these do not statistically differentiate between complaints about basement flooding, yard flooding, etc.

In the 1973 Ottawa Sewer Policy Report, the comparison shown in Table F.5 between Ottawa, Toronto and Hamilton was made on an area-unit basis.

TABLE F.5. FLOODING COMPARISON

	Toronto		Hamilton		Ottawa	
	Total Complaints	Complaints /100 ac.	Total Complaints	Complaints /100 ac.	Total Complaints	Complaints /100 ac.
1970	8,792	36.5	626	5.2	354	2.2
1971	8,170	33.9	628	5.2	565	3.4
1972	7,879	32.7	799	6.7	252	1.5
Serviced Area	24,100 acres		approx. 12,000 acres		16,424 acres	

The detailed records of Ottawa are of statistical interest because they provide an insight into the flooding causes. Complaints were recorded according to three categories of cause:

Type 1 - Sewer Failure
- blockage,
- problems due to sewer reconstruction,
- pumping station failure,
- etc.

Type 2 - Private Drain Problems
- surface or groundwater seeping into basements,
- blockage in private drains,
- flooding from broken water mains,
- etc.

Type 3 - Sewer Overtaxed
- excessive sewer surcharge causing reverse flow through building connections into basements.

Figure F.3 shows the monthly distribution of each of these types during the five-year period from 1968 to 1972, inclusive. Table F.6 shows their relative incidence.

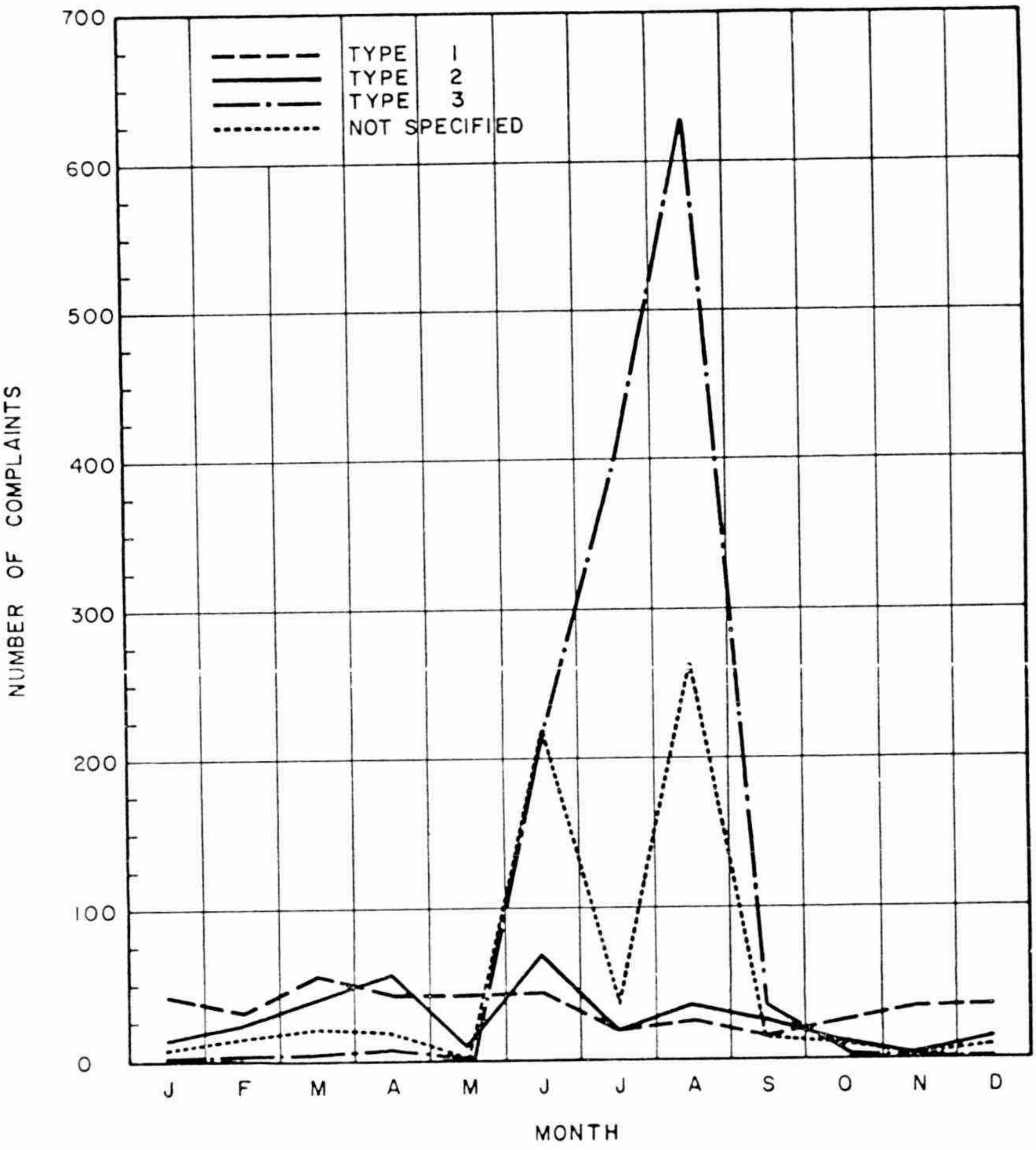
TABLE F.6. OTTAWA - FLOODING REPORTS BY TYPE

	Total	%
Type 1	419	15.4
Type 2	333	12.2
Type 3	1,972	72.4
	2,724	100.0

A comparison of relative flooding incidences was also made between areas of combined sewers and areas of separate systems and is shown in Table F.7.

TABLE F.7. OTTAWA - FLOODING REPORTS BY SEWER SYSTEM TYPE

	Floodings	% Total	Complaints/ 100 ac/yr
Combined sewer areas	1,181	45.1	5.2
Other sewer areas	1,439	54.9	2.3
Total	2,620	100.0	Av.3.1



1968 TO 1972 INCLUSIVE

FIGURE F.3. MONTHLY COMPLAINTS OF BASEMENT FLOODINGS, CITY OF OTTAWA

Percentage comparisons relative to served areas are shown in Table F.8.

TABLE F.8. OTTAWA - RELATIVE FLOODING IN COMBINED SEWAGE AREAS

	% Complaints	% Area	% Complaints / % Area
Combined sewer areas	45.1	26.7	1.7
Other sewer areas	54.9	73.3	0.75

This indicates a higher flooding frequency in combined sewer areas than in separate sewer areas.

F.1.6 Receiving Water Pollution

Within the scope of this report it is not possible to provide a comprehensive overview on receiving water pollution because of the complexity of receiving water pollution problems as well as the difficulties in making geographical comparisons for various types of receiving waters.

A few observations and remarks, however, may be in order with respect to Toronto and Ottawa, based on reports and information collected from these cities.

1) The largest cities provide the most pollution problems, simply because the waste quantities they produce tend to be concentrated in a relatively small area of the receiving water.
2) Notwithstanding the considerable progress in pollution control in the last few decades, the numerous discharges of storm sewer outlets and combined sewer overflows remain a major problem for these cities. Both at Toronto and Ottawa pollution exceeds at many locations the receiving water quality objectives for considerable times each year.
3) Both cities are expending considerable effort and money on pollution abatement, but it is difficult to measure their progress from results of receiving water sampling and analysis.

For instance, after closing of Ottawa's public beaches in 1970, some 4,800 dye tests were carried out in 1971 and 1972 to investigate and reduce polluted overflows. Some 100 cross-connections of sanitary to storm sewers were found and corrected, but this remedial work did not result in appreciable pollution abatement. The 1972 report concluded, among other things, that the major source of pollution may be simple land wash caused by heavy or continuing rainfall. As a result of the study, the municipalities of the Ottawa area have been thrust into the forefront for developing storm water containment and treatment. The results of this work, within the restraints of practical considerations and present technology, however, may take many years of monitoring, analyzing and evaluating before significant results are realized.

4) At any location in receiving waters, it will remain very difficult to establish the proportion of background pollution originating elsewhere in relation to the contribution from the local urban area. This compounds the already complex problem of evaluating receiving water pollution due to the urban source contributions.

F.2 CASE HISTORIES OF MUNICIPALITIES OVER 20,000 - KINGSTON AND CHATHAM

F.2.1 Introduction

The case histories of municipalities of this size are of most interest, because they come closest to the Ontario average for municipalities served by sewer systems in general as well as the average for municipalities that have combined sewer systems and their typical problems.

Moreover, while generally the level and detail of available information is statistically extensive enough to permit assessment of trends and aspects of problems, it tends to be less complex than that of the larger cities. Thus specific problems may more easily be examined and understood.

F.2.2 Historical Information Municipal and Sewer Development

An historical overview, similar to that in the previous section, is provided for Kingston and Chatham in Table F.9.

The contrast in character as cities, between Kingston and Chatham, goes deep enough to even extend to their sewer systems.

Kingston has a long varied history with extensive military and government involvement. It has a relatively high percentage of institutions such as universities and penitentiaries. Its foundations are hilly and on limestone with mostly shallow cover. Its sewage treatment plant was built a considerable distance away from its centre because of the character of the lakeshore line and river flows.

Chatham, on the other hand, with its character of a rural centre, set in the middle of rich farmland with flat topography and clay soils, has seen a relatively quiet but steady agriculturely oriented development. Canning factories dominate the local industry, for instance. With the City straddling the Thames River, historically its main problems have been flooding. Consequently, relative to its sanitary sewer system, its storm sewer system is considerably more extensive than is Kingston's. Yet both cities have about 1/3 of their sanitary systems as combined sewers and the extent of their combined sewer problems is about the same.

F.2.3 Financial Background Comparison

The percentage variations shown in Table F.10 were found in the relative comparison of assessment, taxation, annual expenditures and capital expenditures for sanitation.

As for Toronto and Ottawa, the difference from the provincial average is not great. Chatham's average annual sanitation expenditures are appreciably above those of Kingston and, particularly in recent years, have risen above the provincial average, while Kingston's remained close to it.

Because Chatham is flatter than Kingston, its sewer maintenance costs may be higher, but these costs are a relatively small portion of the overall municipal sanitation annual expenditures. Kingston, being built mostly on limestone bedrock, can expect to have higher construction costs for sewers.

TABLE F.9. KINGSTON AND CHATHAM - HISTORY SUMMARY

City of Kingston		City of Chatham	
Year	Event	Year	Event
1773	Count Frontenac establishes the Cataraqui trading post (Fort Frontenac was destroyed in 1689 and rebuilt in 1696 and again destroyed in 1758 after which the outpost became fairly inactive).	1841	Chatham incorporated as a Village.
		1855	Chatham incorporated as a Town.
		1890	First sewers installed and beginning of water supply by Chatham Waterworks Company.
1783	Cataraqui renamed Kingston; Kingston Township surveyed by Major Holland and village settled by Loyalists.	1895	Chatham incorporated as a City.
1800±	Kingston has become small town with 50 wooden and one stone house - see illustrations of City growth on Figure F.4.	1897	Board of Water Commissioners formed.
		1900	Chatham has reached a population of about 8,800.
1812	Kingston, fortified with Fort Henry, palisades around the town, batteries and a naval dockyard, has grown to 450 dwellings, 3 churches, a library, etc. The growth after the war of 1812 made it the largest town of Upper Canada by 1821.	1959	Annexation of 3,230 acres into the City, an area increase of 153 percent to 5,350 acres total and a population increase from 22,350 to 28,590.
		1967	Sewage treatment plant commissioned (4.5 mgd conventional activated sludge plant).
1826	Construction of Rideau Canal makes Kingston important transhipping port with active forwarding trades and ship yards.	1968	6 aerated lagoons added to the treatment plant to treat tomato canning wastes.
1840	Kingston incorporated as a Town (population about 6,000) followed by incorporation as a City in 1852	1971-1972	New water filtration plant constructed.
1840-1850	Opening of St. Lawrence lands and railway construction reduces the importance of Rideau Canal but Kingston remained an important centre and was the Capital of Upper Canada from 1841 to		

TABLE F.9. (CONT'D)

City of Kingston		City of Chatham	
Year	Event	Year	Event
	1844. Queen's University was incorporated in 1841. Kingston's importance dwindled after Ottawa became the capital in 1858. However, with its civil and military institutions, slowly growing industries, etc. it steadily grew about 3-fold in the next 100 years.		
1952	A large annexation increased Kingston's area from 1,900 acres to 7,485 acres and its population from 33,000 to 42,000.		
1956	Sewage treatment plant built (Primary plant with capacity 9.0 mgd).		
1975	Sewage treatment plant expanded to 13.5 mgd capacity.		

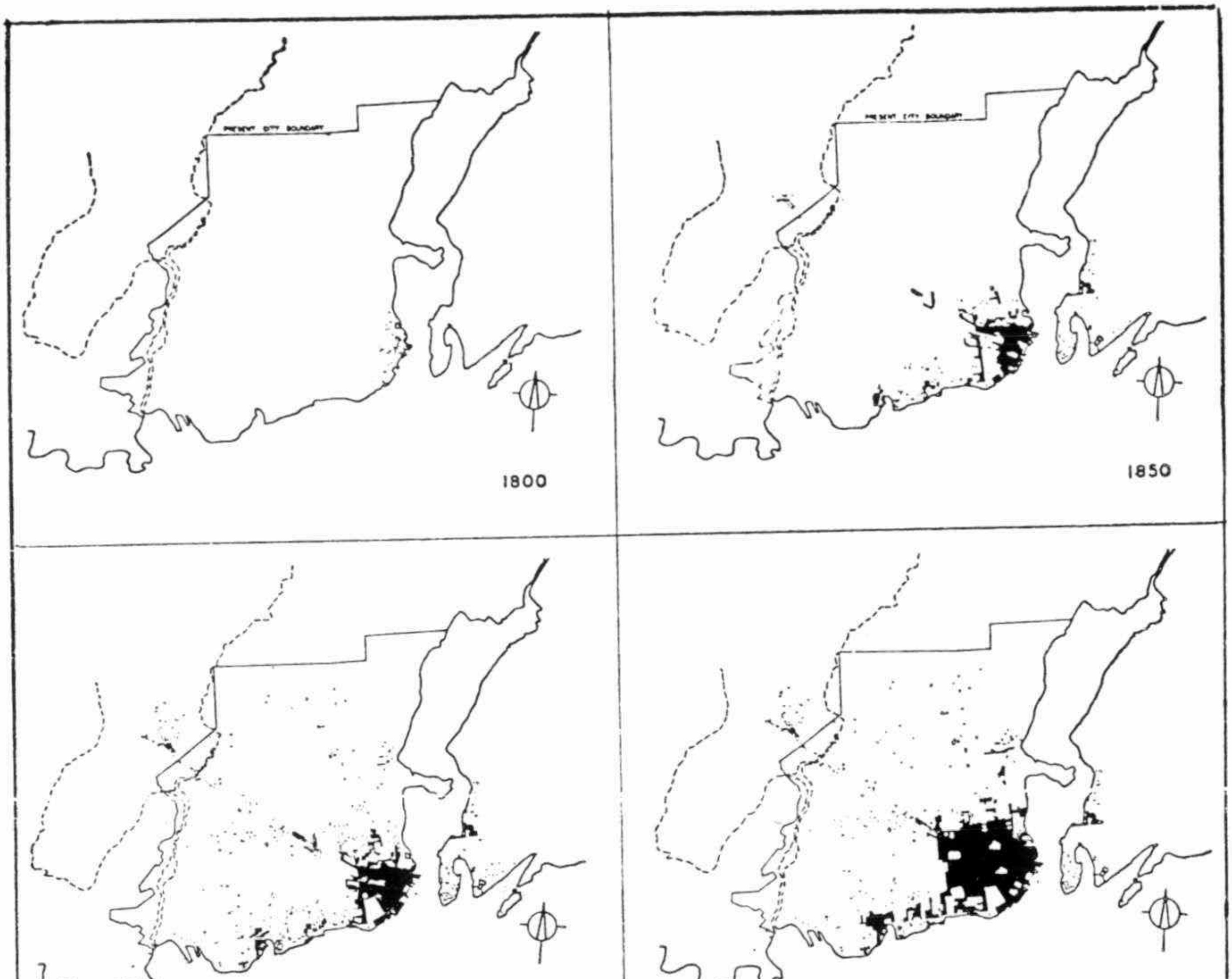


FIGURE F.4. THE DEVELOPMENT OF KINGSTON FROM 1800-1960

TABLE F.10. KINGSTON AND CHATHAM - FINANCIAL FACTORS

	City of Kingston	City of Chatham	Ontario Average
(a) Average percentage of annual sanitation expenditures relative to overall municipal taxation	6.0	7.2	6.0
Maximum variation in above percentages during period of records	1.2 to 12.4	2.7 to 18.0	5.1 to 10.5
(b) Average percentage of capital expenditures for sanitation relative to overall municipal taxation	5.9	5.6	6.0
Maximum variation in above percentages during period of records	0.7 to 19.7	0.1 to 20.4	0.9 to 20.7
(c) Taxation as a percentage of assessment - average for period	7.3	6.3	5.5
Variations in period (see also Ontario graph)	3.6 to 12.8	3.3 to 11.0	3.5 to 8.5

Chatham's pollution control costs are appreciably higher than Kingston's, however. Kingston's primary sewage treatment plant was constructed in 1956 and its capital costs amortized over 20 years. Its 1975 operating costs amounted to $127,483 or $2.09 per capita. Also in 1975, the plant was expanded to 13.5 mgd nominal capacity. In contrast, Chatham's secondary plant as constructed in 1965-1968 carries not only appreciable debt charges but its operating costs alone exceed $10.00 per capita. Moreover, Chatham, because of its flatter nature needs to do more sewage pumping, with its associated costs. It also has to handle relatively expensive canning wastes and experiences high sludge disposal costs.

F.2.4 Kingston's Operations and Their Costs

A more in-depth analysis of Kingston's sewer problems, and particularly combined sewer problems, together with a detailed analysis of Kingston's annual sanitation costs, may be of interest as a typical "case history" analysis.

TABLE F.11. CITY OF KINGSTON - PUBLIC WORKS COSTS

	1974	1975
A. Public Works Scope		
Main engineering staff number (office)	34	35
Total public works staff (including part time help)	225	215
Equipment inventory - refuse collection	12	13
- other mobile equipment	102	106
Awarded contracts (work by outsiders)		
- number	15	24
- total amount	$2,414,000	$2,556,500
B. Public Works Quantities		
Total length of roads (miles)	108.19	108.65
Total lenght of sidewalks (miles)	151.89	153.42
Total length of sewers (miles)	151.91	154.67
of which combined sewers (miles)	38.20	38.11
sanitary sewers (miles)	73.52	64.64
storm sewers (miles)	40.19	41.92
Sewage treatment plant flow - mgd	12.8	13.5
Number of pumping stations	10	11
Total installed horsepower	2078½	2079
Population served	60,425	61,003
C. Public Works Annual Costs		
a) Roads and sewerage works	$1,783,471	$1,885,799
b) Garbage collection and disposal	627,371	786,977
Total annual sanitation costs	$2,410,842	$2,672,776
Percentage of total city budget	11.34%	11.98%
a) Roads and sewerage works - detailed expenditures - percentage of total costs	(of $1,783,471)	(of $1,885,799)
1) General Administration	4.6%	4.4%
2) Engineering	9.8%	10.2%
3) City yard service	3.5%	3.8%
4) Maintenance of sidewalks	2.5%	3.6%
5) Permanent pavement work	14.0%	15.3%
6) Unpaved road work	3.7%	3.8%

TABLE F.11. (CONT'D)

	1974	1975
C. Public Works Annual Costs (cont'd)		
7) Winter control works (included snow removal)	24.9%	22.1%
8) Sidewalk sanding and snow removal	4.4%	4.4%
9) Street cleaning	7.7%	6.4%
10) Maintenance of sewers	10.5%	10.6%
11) Sewage pumping stations	8.2%	8.6%
12) Water pollution control plant	6.2%	6.8%
Total Roads and Sewerage Works	100.0%	100.0%
D. Capital Works Costs (exclusive of subsidies)		
a) Local Improvements		
1) Road reconstruction	$ 125,000	$ 25,000
2) New construction - roads	210,708	85,000
3) Sanitary sewers	242,177	473,250
4) Storm sewers	340,000	225,000
5) Sidewalk construction	106,890	6,000
b) General Rate Works		
1) Road reconstruction	262,000	25,000
2) Sidewalk reconstruction	---	19,000
3) Sanitary sewers	220,000	---
4) Water pollution control	120,000	---
Total	$1,626,775	$858,250
Percentage of total city capital works budget	63.30%	73.18%
E. Miscellaneous		
a) Equipment purchases	$ 54,225	$153,066
b) Subsidies		
1) Pavement construction (usually includes storm drainage)	370,000	440,000
2) Suburban roads - County's share plus subsidy	193,500	198,000
Total	$563,500	$638,000
c) Unit costs of maintenance work items per mile		
1) paved roads (including catch basins, etc)	$2,574	$3,001
2) Unpaved roads	4,426	5,552
3) Sidewalks	290	444
4) Street cleaning	1,258	1,344
5) Sewer maintenance	1,225	1,293
6) Snow removal, road sanding and plowing	4,073	3,822
7) Sidewalk sanding and plowing	531	558

General costs and other statistical information are presented in Table F.11. Because some items of annual information may be extreme in a given year, both 1974 and 1975 statistics are given to reflect the current background status, with most information being derived from the annual public works reports.

The capital works costs, under Item D of the table, include the costs of various sewer works, which may be categorized as sewer improvements, sewer separation works, new storm sewers and trunk sewer improvements.

The capital works budgets tend to be a given percentage of the overall city budget and, for the coming five years, capital expenditures on sewerage works in Kingston will be in the order of one million dollars a year.

For example, the 1977 sewerage works budget is made up as follows:

TABLE F.12. KINGSTON - 1977 SEWERAGE WORKS COSTS (approximately)

(1)	Northwest area sewer improvements	\$ 74,000
(2)	General sewer separation works	\$500,000
(3)	New storm sewers	\$300,000
(4)	Northern trunk sewer improvements	\$ 90,000
(5)	Miscellaneous sewer improvement works	\$ 90,000

In addition, in 1978 and beyond, about \$100,000 per year will be expended on WPCP improvements.

This budgeting reflects Kingston's current sewer problems, which are perhaps typical of many municipalities. First, the problem foremost in the public (taxpayers') mind is flooding. Although this is not relatively as serious a problem in Kingston as in most other municipalities it is primarily caused by storm flows exceeding the sewer system's capacities. In areas with combined sewers, capacity improvements generally go hand-in-hand with sewer separation, and in areas with separate sewers, primarily new storm sewer construction is needed to overcome these problems. Above budget items (2), (3) and (4) are all for such works and constitute most of the capital expenditures on sewers in

Kingston, while items (1) and (5) are primarily for rectification of flows in the sewer systems, but again basically to either improve capacity or reduce extraneous flows.

Sewage pollution control is not considered to be a major problem by the City of Kingston. Kingston is located at the downstream end of Lake Ontario, i.e. at the upper end of the St. Lawrence River. Dilution and diffusion in the river will reduce the effect of the pollution from Kingston fairly rapidly downstream. Kingston has no major industrial problem as compared with many other cities (Chatham with its canning wastes, Ottawa with its paper plant wastes, etc.).

Kingston also has a city dump, now closed, which extends into the Bay of the Great Cataraqui River above the causeway and drains leachate into the Bay and Lake Ontario. This has caused relatively high pollution for many years. Against this background it is difficult to actually measure and quantify the degree of pollution from the City's combined sewer overflows which have outlets all along the water front.

A more detailed appreciation of Kingston's sewerage problems may be presented, however, by considering the city's sewer system as follows:

TABLE F.13. KINGSTON - SEWER SYSTEMS LENGTH

Sanitary Sewers	74.64 miles or 66% of total sanitary system
Combined Sewers	38.11 miles or 34% of total sanitary system
Total Sanitary Sewers	112.75 miles (100%)
Storm Sewers	41.92 miles or 52% of total storm drain system
Total Storm Sewers (including combined sewers)	80.03 miles (100%)

Percentage of overall sewer system:

Sanitary Sewers	48.3%
Combined Sewers	24.6%
Storm Sewers	27.1%

Nearly all combined sewers are located in the city's core. This is the city area of about 1,900 acres before the 1952 annexation,

mainly located in the Great Cataraqui River watershed and areas draining directly to Lake Ontario. The 5,585 acre area of Kingston Township annexed in 1952 was mainly served by separate sewers and all new sewers in this area have been constructed as separate sewers. Most of this added area is located within the watershed of the Little Cataraqui River.

In the late 1950s, with the construction of the Sewage Treatment Plant, an intercepting system was constructed along the water fronts of Lake Ontario and the Great Cataraqui River. Trunk sewers and pumping stations convey the sanitary flow from the surrounding annexed area into this interceptor. Where sanitary sewers could be connected directly into the upstream sections of the combined system, these, in effect, became semi-combined systems, but most of the sewer systems in the annexed area should be considered separate systems.

There are major problems of inflow and infiltration in these separate systems, however, especially in the northwest area. A 1974 study indicated costs for rectification of these problems to be approximately \$0.94 per gallon of infiltrating water.

A pragmatic approach, primarily based on minimum cost considerations, resulted in the following program:

1) Improvement in pumping capability for the northwest area to handle a reasonable portion of the excessive infiltration; the cost for pumping and treatment of the excess flows being lower than that of total rectification of <u>all</u> flows into the system.
2) Reduction of inflow and infiltration where practicable at relatively low costs, using the above assessment as a guide for the cost effectiveness of remedial works.

F.2.5 City of Chatham Sewer System and Problems

The development of Chatham's drainage systems and its problems are closely related to its topography and, in particular, to the conditions caused by the Thames River which flows through the heart of the city.

Chatham is located on the lower part of the Thames where the river meanders through the flat lands. The upper part of the Thames with

its large watershed of 2,200 square miles is relatively much steeper causing rapid storm runoff to the lower part.

At Chatham, low indistinct ridges called natural levees border the river channel. In Figure F.7 area and local profiles both show clearly these ridges. They were formed when the river was in flood and spilled over its flood plain, which immediately decreased the (lateral) velocity and turbulence causing deposition of its suspended solids load. The ensuing general cross profile (Figure F.7) illustrates this.

In their natural state the levees prevent return of the flood water directly to the river, causing the area to be drained by a series of long and shallow drainage ditches and watercourses that run parallel to the river and empty into it some miles away from Chatham. Poorly drained areas and shallow swales cover the area.

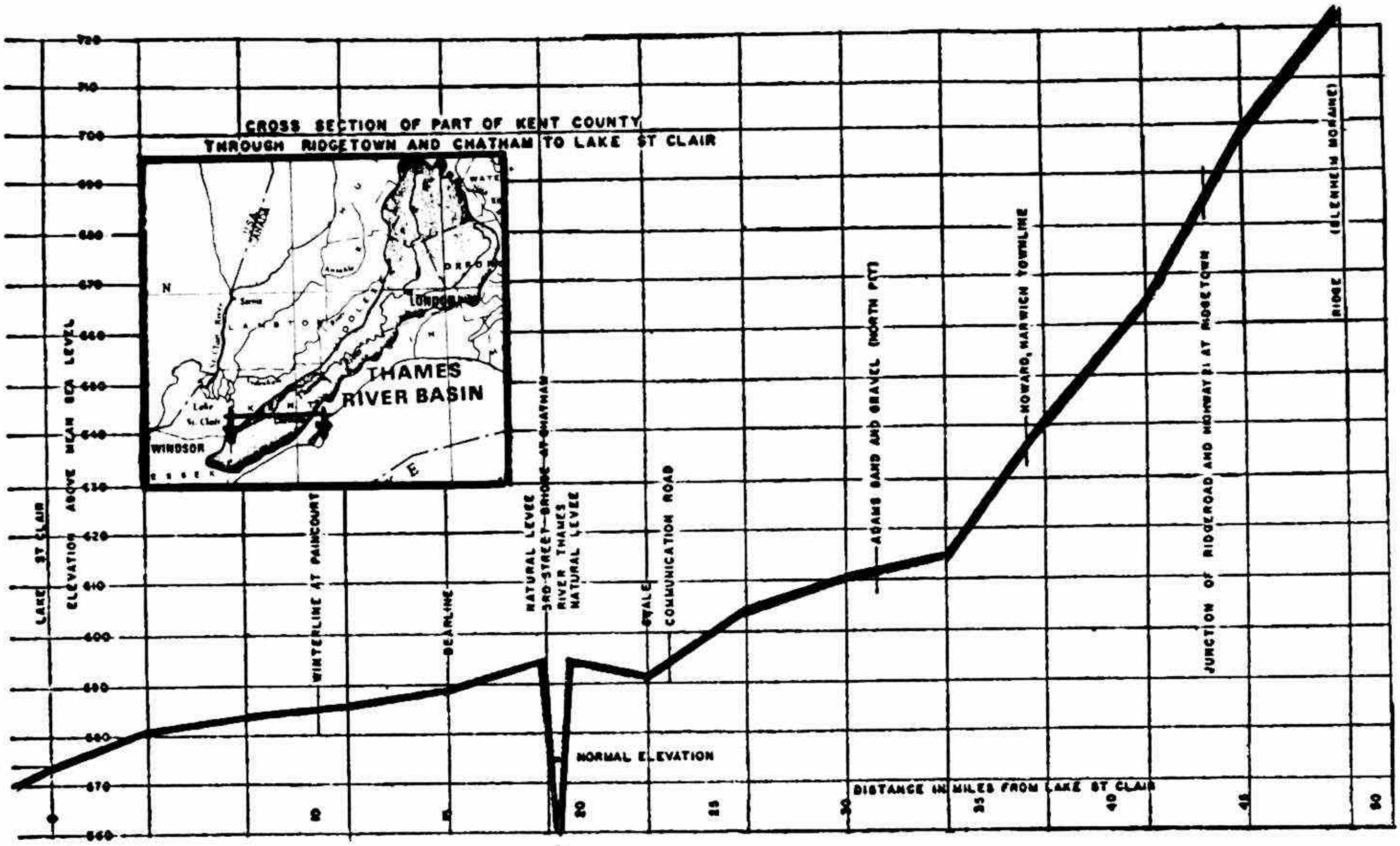
Settlement started along the river where the ground was highest. With the development of drainage and sewerage, cuts through the natural levees were made for draining into the river but this breaching permitted flood waters from the Thames River to back up and flood the serviced low lands. Floodgates would prevent the backing up of such drains but the lands would still flood for temporary lack of an outlet.

In 1883 the MacFarlane Drain was constructed but, because of this problem, in 1912 the MacFarlane Relief Drain was constructed westerly parallel to the Thames River to Lake St. Clair. This storm relief is most important for the City to minimize flooding problems.

As shown in the "Gumbel" probability charts in Figure F.8, river flooding at Chatham may cause a flood crest from five to nearly 20 feet above normal level, with an accompanying large increase in discharge quantities in the River.

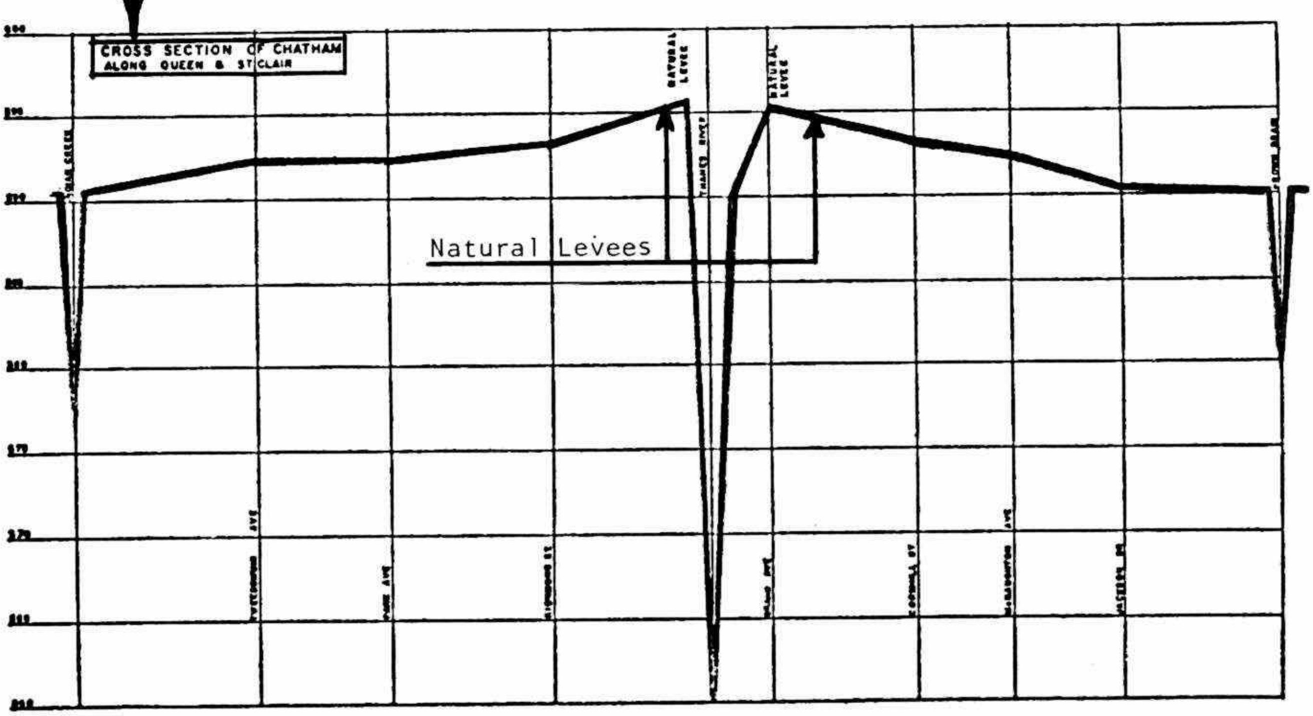
Under these conditions one might expect the city's sewer system to be completely separate because this would minimize basement floodings, but in the gravity discharge to the river of both storm water and sanitary sewage for many years, the first sewer systems were constructed as combined sewers.

Pollution control for protection of the river became an issue only about 20 years ago and a trunk interceptor sewer system and Water Pollution Control Centre were constructed in the early 1960s to convey and treat the sanitary flow.



A. From Lake St. Clair to Ridgetown

Cross Profiles of Thames River Area
to illustrate special drainage problems



B. Locally at Chatham

FIGURE F.7. CROSS PROFILES OF THAMES RIVER AREA TO ILLUSTRATE SPECIAL DRAINAGE PROBLEMS

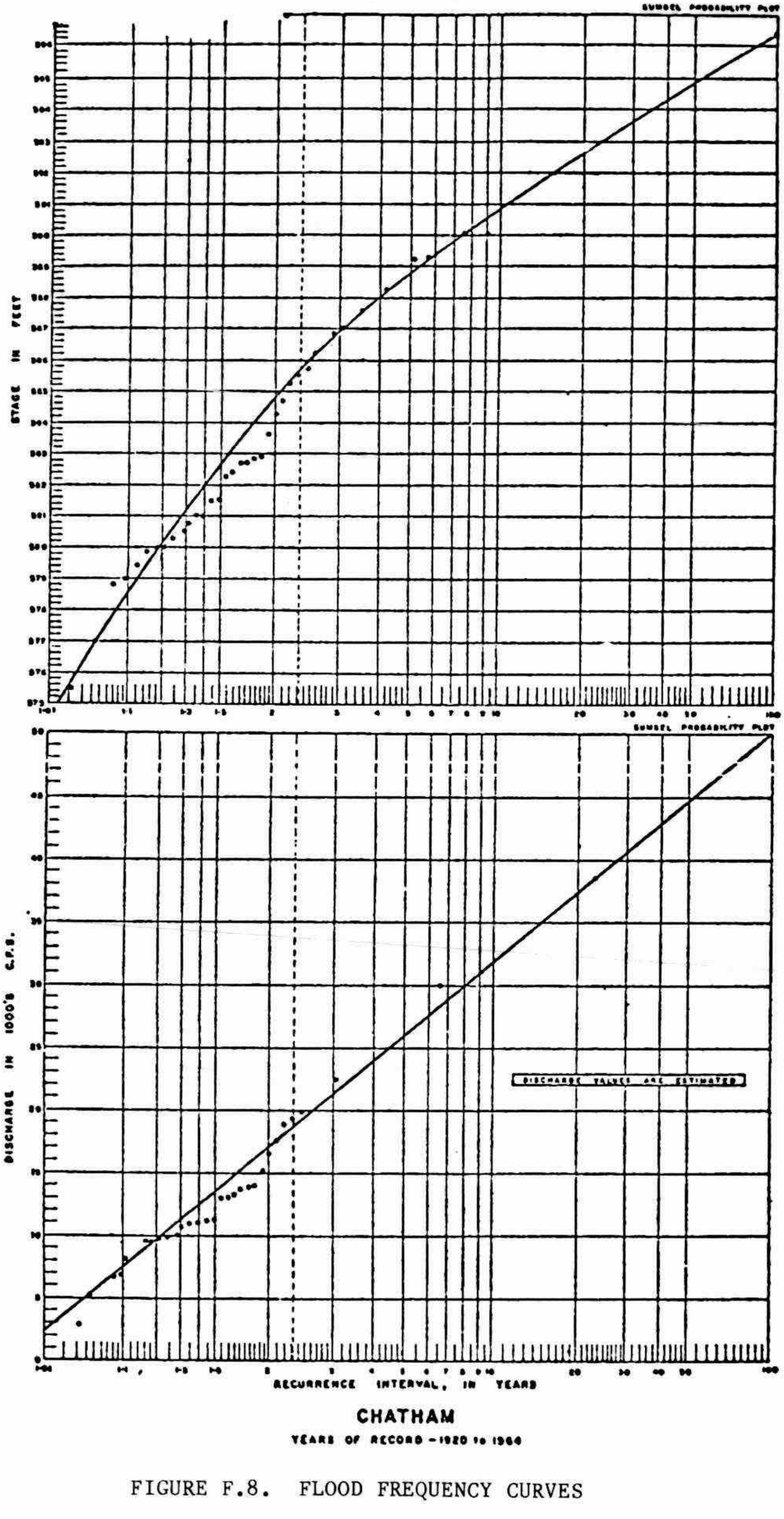


FIGURE F.8. FLOOD FREQUENCY CURVES

Development of the sewer system with continuous breaching of the natural levee compounded Chatham's flooding problems and also caused certain legal problems. For instance, in 1919 the "Rhodes" Dam was built, after several years of litigation, to provide a certain diversion of creek waters. This invoked the comment that when the Indians were in charge, flood water could flow west relieving the flooding but when the British came, they brought their Common Law which can "deny the right of water to run downhill".

For its municipal size, Chatham has relatively numerous pumping stations. On the sanitary and intercepting system alone there are 11 pumping stations and, as may be seen on the ultimate scheme in Figure F.9, five more stations will be added in the future. Furthermore, there are three storm water pumping stations.

The extent of Chatham's combined sewer systems relative to its overall sanitary sewer network is not high. Of the six case histories, Chatham ranks fourth with 39 percent combined sewer footage of its total sanitary sewer length (Campbellford - 90%; Toronto - 84%; Thorold - 56%; Kingston - 34% and Ottawa - 33% in comparison). However, because of its special topographical and hydrological characteristics and, consequently, somewhat unique sewer system with respect to flooding control, its combined sewer overflow system is fairly complex.

The plan in Figure F.10 illustrates the spread in location and the variety of means for controlling combined sewage overflow to storm systems and receiving water.

Where sanitary sewers were built near a new storm sewer system they were interconnected to allow for overflow from one to the other depending on which was in trouble. This was not considered serious until 1968 because <u>all</u> sewage went to the river without treatment until that date.

In the 1974 report on the sewerage system of the City of Chatham, the matter of combined sewer overflows was studied to a considerable extent and is worthy of further consideration here.

The report lists 66 combined sewer overflow locations of which 29 are provided with flood gates. One of the reasons for investigating their operation was the significant flow increase experienced at the

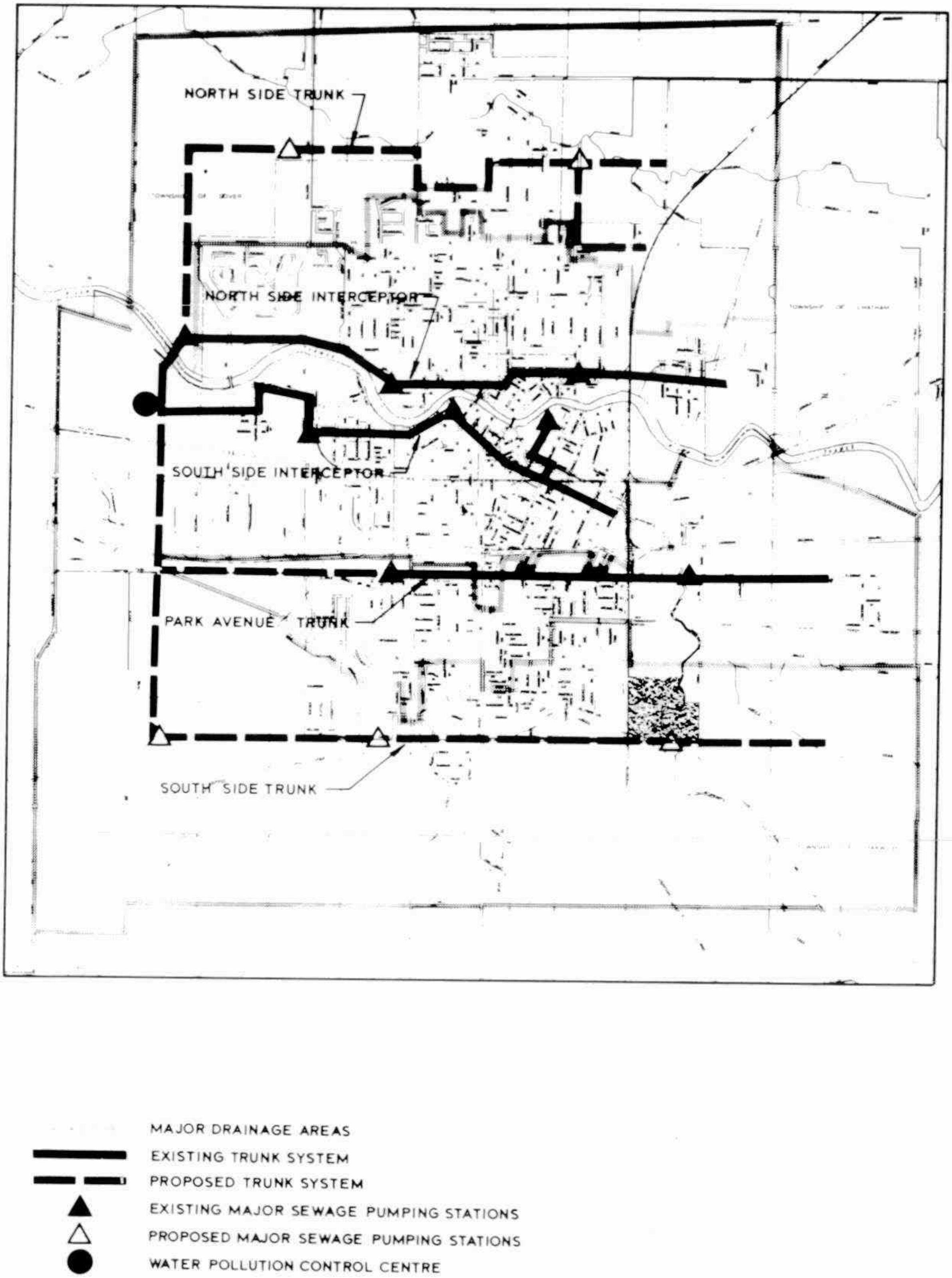


FIGURE F.9. ULTIMATE SCHEME FOR SANITARY SEWAGE COLLECTION, CHATHAM

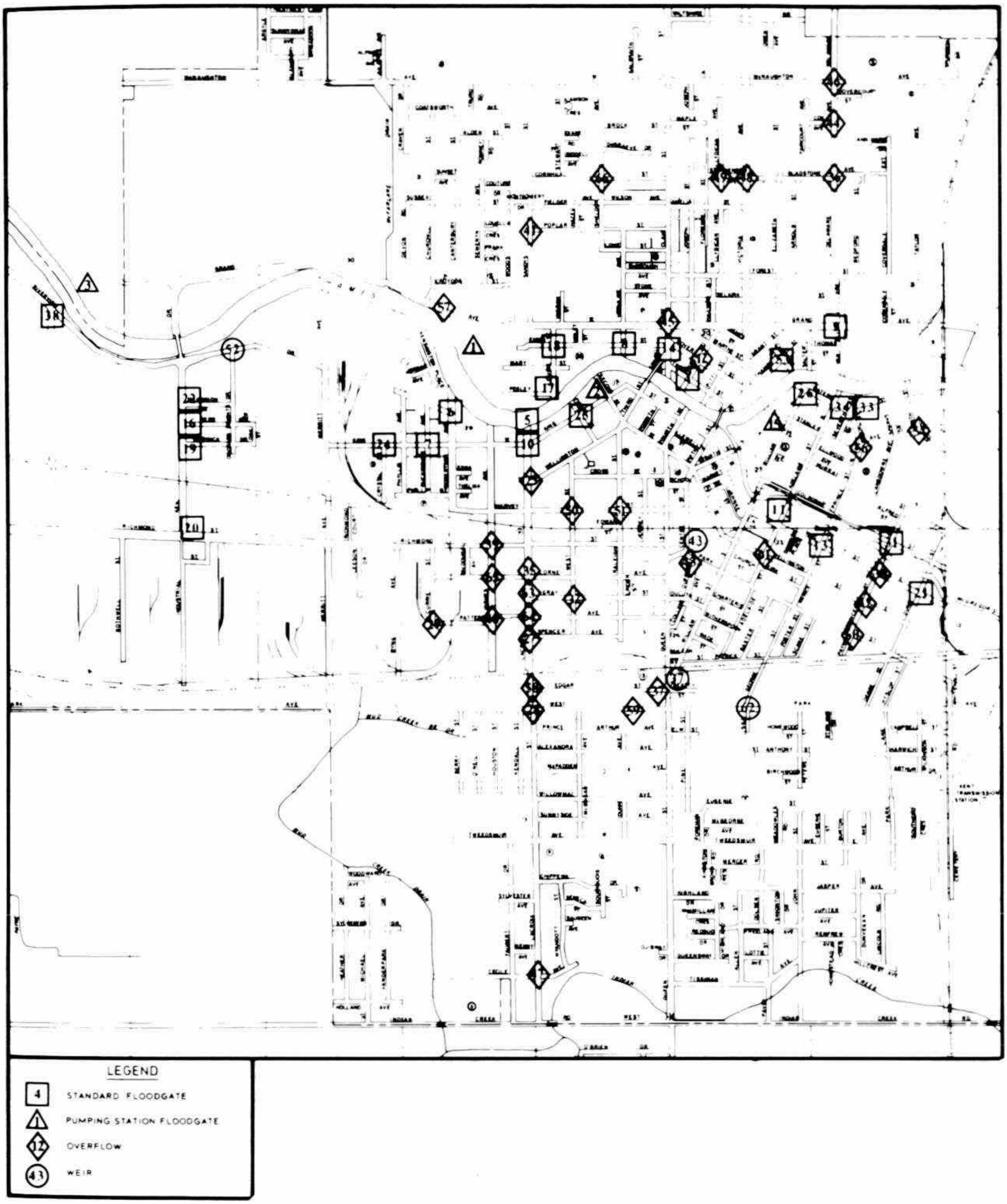


FIGURE F.10. LOCATION OF COMBINED SEWER OVERFLOWS, CHATHAM

Water Pollution Control Centre in the years 1972-73, which appeared to be correlated to a certain extent with the river level fluctuations.

The starting point of the report's consideration of the effects of combined sewer overflows in Chatham, in relation to its intercepting system, is the result of an investigation in the U.S. for an area with reasonably similar conditions.

The graphs in Figures F.11 and F.12 appear to be generally applicable, assuming that Chatham's interceptor system is functioning at peak capacity and the recommended alteration of 27 of the 66 overflow devices is realized.

Application of this combined overflow frequency analysis to Chatham's system and conditions resulted in Table F.14, which shows that the volume of overflows may become less than 1 percent of the flow conveyed to treatment. There is insufficient data to assess the present volume of overflows, but it is considerably higher than tabulated in Table F.14.

Table F.14. FREQUENCY AND QUANTITY OF STORM SEWER OVERFLOW FOR A ONE-YEAR RETURN PERIOD IN THE CITY OF CHATHAM

	Pumping Station Data			Volume of Overflows			
Name	Capacity (mgd)	Existing Average Flow (mgd)	Number of Times DWF	Total Average Yearly Flow (MG)	Percentage of Flow Lost	Volume of Overflow (MG)	Frequency of Overflows
Van Allen	0.99	0.41	2.41	150	0.9	1.35	28
Grand Avenue West	4.50	1.41	3.2	515	0.7	3.60	24
River Road	5.40	1.83	3.0	668	0.8	5.30	26
Tecumseh	0.90	0.06	15.0	22	<0.1	-	-
YMCA	6.41	1.02	6.3	372	0.2	0.70	10
Merritt	20.55	2.79	7.4	1,018	0.1	1.00	7
		TOTAL		2,745		11.95	

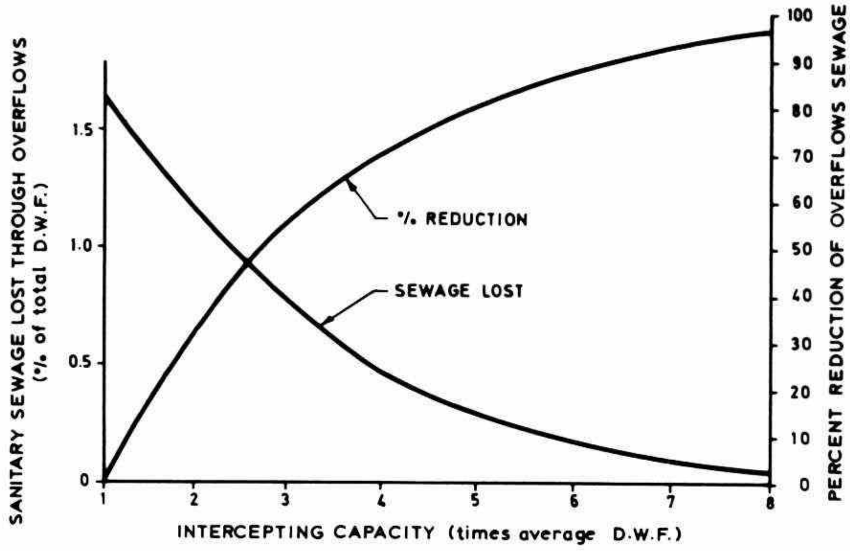


FIGURE F.11. RELATIONSHIP OF SANITARY WASTEWATER LOSS TO INTERCEPTING CAPACITY, CITY OF CHATHAM

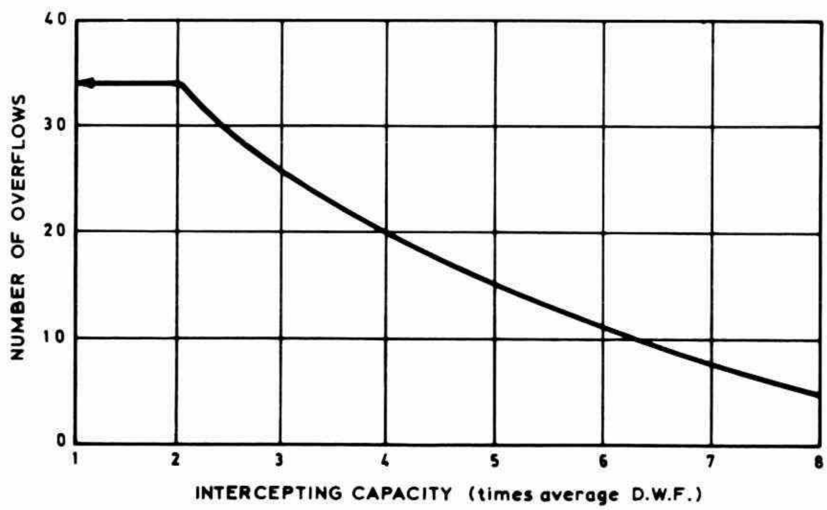


FIGURE F.12. RELATIONSHIP OF NUMBER OF OVERFLOWS TO INTERCEPTING CAPACITY, CHATHAM

The report concludes, on the basis of the above findings, that a separation program for Chatham's combined sewer system may not be considered as a high priority. This applies, of course, to a well operating system of interception and overflow controls which is generally found to be a problem with many intercepting sewers. They may be well designed and constructed, but if not well maintained and regularly checked for operation conforming to design intentions, they may become a significant source of combined overflow pollution as well as treatment plant overloading and bypassing. Much of the overloading of the sanitary sewer system was found to be due to improper maintenance and inefficiency of flap valves that let river water back into the intercepting sewers.

In the analysis of the sources of high sewage flows at the Chatham Treatment Plant, the following source possibilities were considered:

1) New service connections: Their number was found to be minimal as compared to the flow increases which were noted.
2) Water consumption: The addition of a high water consumer on the system can result in appreciably higher flows, but in this case such contribution was not a major factor. The cannery needs are mainly responsible for this high per capita use.
3) Infiltration from rainfall: As above normal rainfall and subsequent rise in the groundwater table can cause higher infiltration rates, especially in sanitary sewers relative to their dry weather flow, many rainwater leaders go to the combined sewers.
4) High river levels: These may cause both higher infiltration because of their effect on the groundwater table as well as backflow into the system, where backflow prevention devices are inoperative or operating poorly. A number of instances of such backflow occurrences were recorded by several parties.

A statistical indication that backflow was the main cause of abnormal flows at the treatment plant was obtained from Table F.15.

TABLE F.15. COMPARISON OF AVERAGE ANNUAL SEWAGE FLOW TO RIVER LEVEL, WATER CONSUMPTION AND RAINFALL, CHATHAM

Year	Average Yearly Sewage Flows (mgd)	Average Yearly River Level (feet)	Average Yearly Water Consumption (mgd)	Annual Rainfall (inches)
1967	3.1	574.80	4.3	38.30
1968	3.8	574.90	4.3	35.11
1969	4.1	575.25	4.4	38.72
1970	3.7	575.55	4.4	27.00
1971	3.3	575.55	4.5	24.74
1972	4.3	576.35	4.4	32.42
1973	4.7	576.85	4.7	32.97

Because the above statistics are indicative but far from conclusive, a further analysis was carried out by relating plant flows to river elevations. The resulting graph is shown in Figure F.13. It confirmed that much of the excess flow at the plant may be attributed to inflow at the combined overflow devices during times of high river levels.

Of the several types of overflows in Chatham essentially two major ones may be distinguished:

a) In areas where the river level is higher than the existing sewers, flap gates are used to prevent backflow.

b) In other cases weirs or orifices or both are used to control the overflow and rate of interception.

Typical examples of the types of overflow chambers in Chatham are shown in Figure F.14.

In Chatham, the pumping station overflows particularly have been a major source of trouble. River backflow in these structures is also prevented by flood gates. These are mainly set below average river level, so that for much of the year they are submerged and under significant back

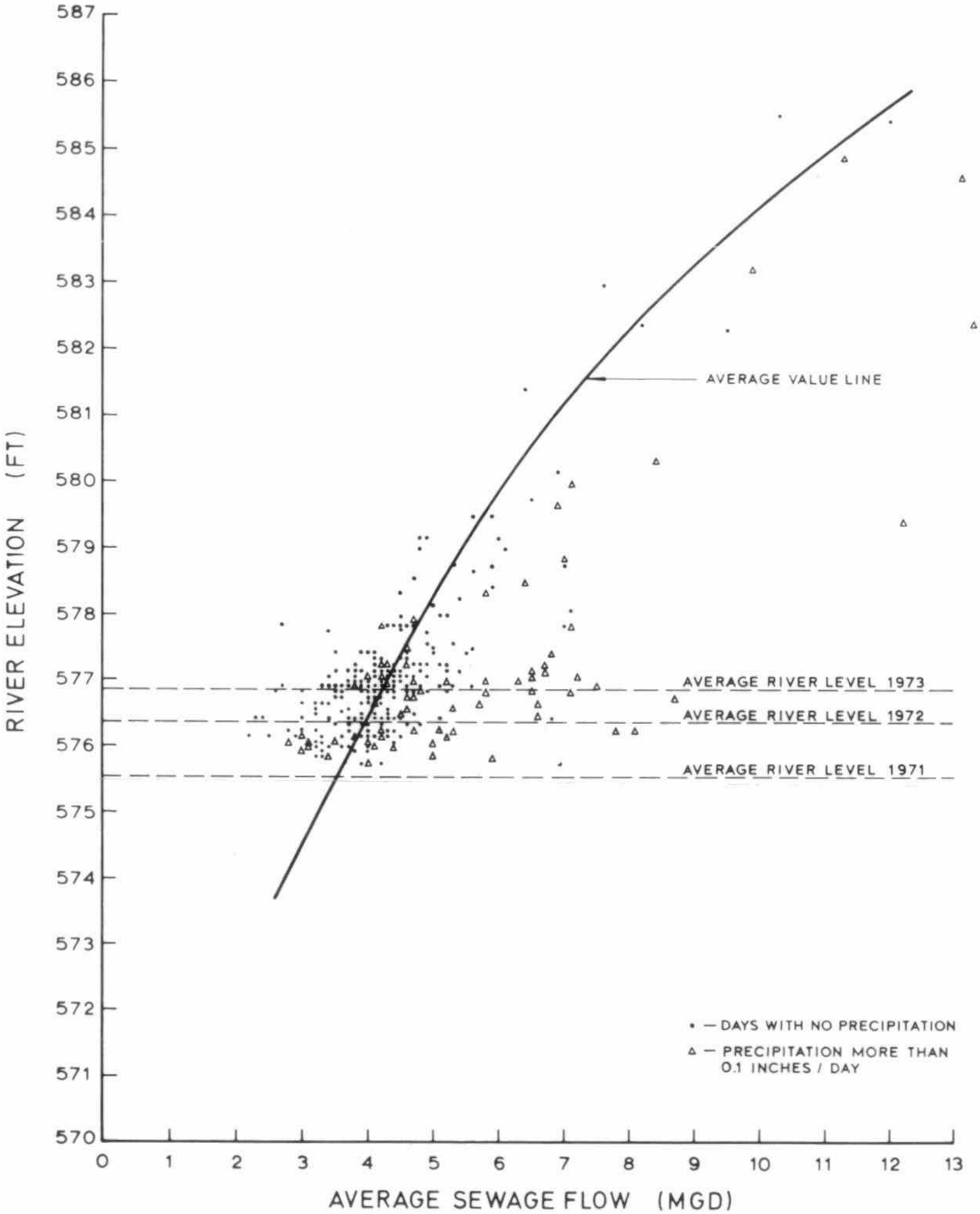
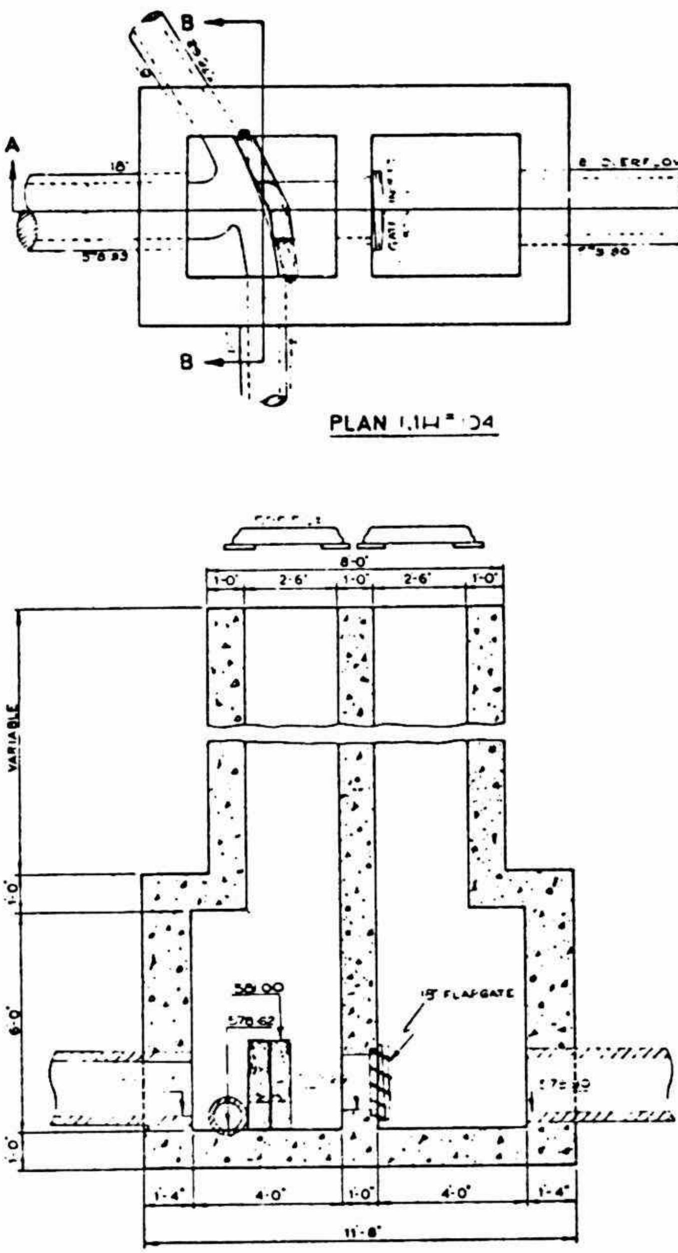
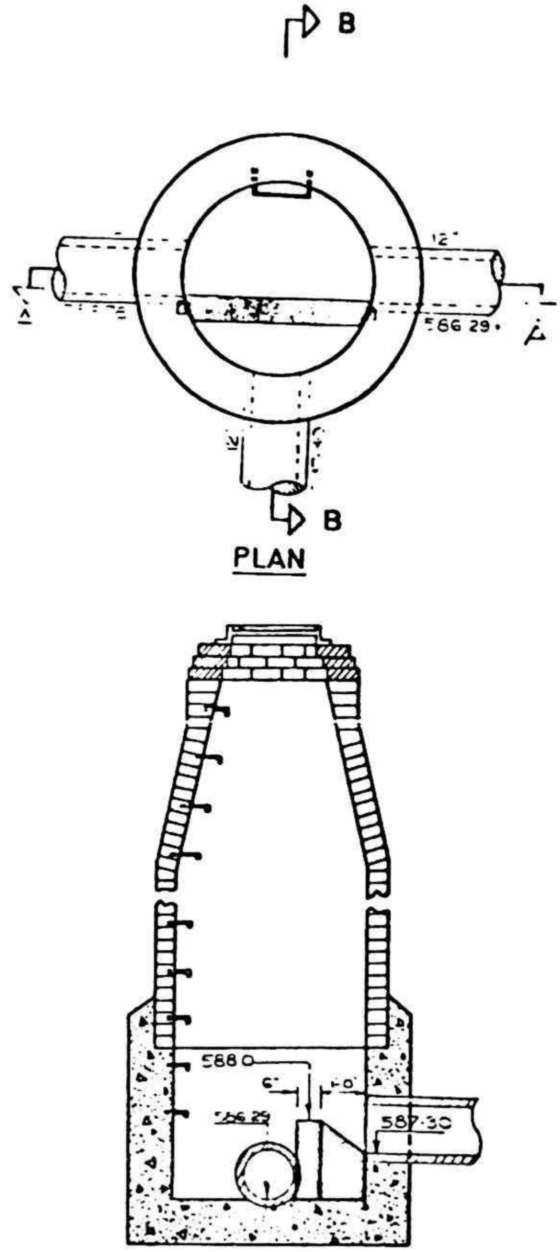


FIGURE F.13. DAILY RIVER ELEVATION VERSUS AVERAGE DAILY SEWAGE FLOW, CHATHAM



SECTION A-A

TYPICAL FLAPGATE STRUCTURE



SECTION B-B

TYPICAL OVERFLOW CHAMBER

FIGURE F.14. OVERFLOW CHAMBERS, CHATHAM

pressure heads created by the river. Because of the construction of the chambers, many of these flaps cannot be seen from above to determine whether they are jammed open by debris or unlubricated flap hinges.

F.3 CASE HISTORIES OF MUNICIPALITIES UNDER 20,000 - THOROLD AND CAMPBELLFORD

F.3.1 General

The case study of Thorold which, with its recent change in status to the City of Thorold encompassing the former Town of Thorold and Township of Thorold, will give emphasis to the actual original Town area. This "Town" area with its population of about 9,000 may, in general, be reasonably compared with Campbellford with its population of 3,000.

F.3.2 Historical Background

As before, the histories of both municipalities may be compared side by side (Table F.16).

Although canal building has had an appreciable impact on both municipalities, their primary prosperity has depended and still depends on their industrial development. At the beginning of this century, they were about the same size, but Thorold was more fortunate with its much larger influx of industries, while Campbellford tended to decline with the decline of farming in eastern Ontario. The Welland Canal has become a major shipping lane on the Great Lakes waterway and as such has had an influence on Thorold's growth.

Provisions for sewage treatment are fairly recent for both municipalities. Campbellford, however, had to construct its own facility, while Thorold could make use of outside facilities at much lesser costs.

Thorold's main sewerage works are now part of the Niagara Region's system with all the benefits of economies of scale, while Campbellford is on its own. This emphasizes that the smaller, lower-income municipalities tend to incur relatively higher sanitation costs than do the larger municipalities. The larger municipalities have, however, generally a large per capita taxation, because they have many other expenditures, which tend to be less significant in the smaller municipalities.

TABLE F.16. THOROLD AND CAMPBELLFORD - HISTORY SUMMARY

CITY OF THOROLD		TOWN OF CAMPBELLFORD	
Year	Events	Year	Events
1792	First settlement in Township area (with first municipal business meeting in 1799).	1876	Campbellford incorporated as a Village, serving as a centre for the surrounding rural area.
1817	Township population grown to 830.	1901	Population has reached 2485.
1824-1829	Building of first Welland Canal (in 1833 extended to 27.5 miles).	1906	Campbellford incorporated as a Town.
1840-1845	Building of second canal with enlargement of original canal at Thorold.	1910	Trent Canal built through the middle of town which raises groundwater appreciably, causing certain sewer problems. The Town's major trunk interceptor sewer is incorporated in the canal walls as a "Core Wall Sewer".
1850	Incorporation of Thorold as a Village (with population grown to 1200).	1911	Town population grown to 3057 but decreased between 1911 and 1931.
1854-1857	Construction of the Great Western and Welland Railways.	1927-1928	Major portion of present sewer system constructed, together with paving of the town's streets.
1870-1887	Building of the third canal (new route from Port Dalhousie to Allanburg).	1931-1971	Population growth from 2744 to 3470, with Town remaining local service centre for rural area with declining farming, modest tourism and mainly secondary industries.
1875	Incorporation of Thorold as a Town (population grown to 2540 by 1884).	1956±	Start of largest industry in Campbellford: "World's Finest Chocolate".
1904-1905	Lake Gibson (Klondike Works) constructed by Hamilton Cataract Power Co. These artificial shallow lakes or ponds now serve to receive storm overflow from newer development.	1970-1971	Construction of a (new) 0.8 mgd Sewage Treatment Plant.
1912-1914	Large influx of major industries such as paper mills.		
1913-1932	New Welland ship canal built with main locks in Thorold.		

TABLE F.16. (CONT'D)

City of Thorold		Town of Campbellford	
Year	Event	Year	Event
1954-1965	Old Welland Canal cleaned up and made into storm drain. Used for five years as a sanitary drain until pumping into St. Catharines S.T.P. facilities was provided.		
1960	Change of Town boundaries increases population about 3 percent.		
1970	Town of Thorold and Township of Thorold amalgated as the City of Thorold within the formed Region of Niagara. The population increases 72% to 153,000. The area increase to 20,069 acres adds to the original three centres, Thorold, Thorold South and Allanburg, a fourth centre named Port Robinson.		

In general character, and consequently in scope of sewer systems and their problems, there are considerable differences between these two municipalities. Campbellford, although bisected by the Trent Canal is a fairly concentrated homogeneous town. Thorold, however, consists of several distinct centres. This has even become more pronounced with the amalgamation of the Town and Township of Thorold into the City of Thorold. The Town of Thorold consisted of the original development, bisected by the old canal, with the new canal constructed more to the east, a separate urban development adjacent to industries, now called Thorold South, and still more southerly a third separate development known as Allanburg. The most northerly old Town of Thorold (Thorold North) now joins St. Catharines as a homogeneous urban development, with the municipal boundaries providing only an artificial dividing line. (Within the Niagara Region, St. Catharines, Thorold, Thorold South and Allanburg together form Sanitary Sewer District No. 2.)

This has its impact on the sewerage systems and problems, which can only be very generally compared in these two smaller "towns", Thorold and Campbellford. But in deeper analysis each is unique with respect to its development and sewer systems.

As shown in Table 10 with respect to the extent of combined sewers, Thorold (in its three centres as a total) has about 56 percent of its sanitary system as combined sewers, while in Campbellford 90 percent of the sanitary sewers are combined. The historical development of these sewer systems differs considerably as well. Thorold's first sewer development consisted of separate sanitary sewers, which to a certain extent were later modified by the connection of a limited number of catch basins.

Only in its second stage of sewer development were outright combined sewers constructed. Later this practice was entirely discontinued. Thorold's combined sewers are, therefore, located in a separate drainage area. In contrast, Campbellford's separate sewers have only more recently been constructed in new development areas so that it has a relatively large core of combined sewers.

F.3.3 City of Thorold Sewer Systems and Problems

Generally, the available information on smaller municipal systems and their problems tend to be more limited in scope than in the middle-size and larger municipalities, but it is still of interest for this study. In the case of Thorold, with its three urban centres, the two smaller centres, in particular, have more the character of small villages, with well-developed sanitary systems and limited storm sewers, as most storm drainage is conveyed by road ditches. Their relative size may be appreciated as follows:

TABLE F.17. URBAN CENTRES IN THOROLD

Total population of the City of Thorold	14,700±
Total population of the three urban centres: Thorold, Thorold South and Allanburg	8,900± or 60%±
Population of Thorold (old Town area)	6,600± or 45%±
Population of Thorold South	2,000± or 13%±
Population of Allanburg	300± or 2%±

A 1970 report on the actual original Town area sewer system of Thorold with its combined sewers provides the most comprehensive information on the system.

Plate 10 of the report, reproduced in Figure F.15, shows the original separate sanitary collection system as installed between 1911 and 1919. This system served a population of about 4,400. As noted before, it was designed for sanitary flows only, but became a convenient solution to the problems of the 1920s, 1930s and 1940s when roads were hard-surfaced and surface drainage was improved. During the 1950s several relief outlets were built.

With the rapid expansion of the Town in the years 1947 to 1954 to the west, the "Chipman and Power" sanitary collection system was extended with a combined system in part of the area. Because of overloading of the old system and to relieve flooding, storm sewers were installed with other extensions. Finally, in the development of all subdivisions after 1959, all new sewer systems were designed as separate storm and sanitary systems.

TOWN OF THOROLD SEWER STUDY

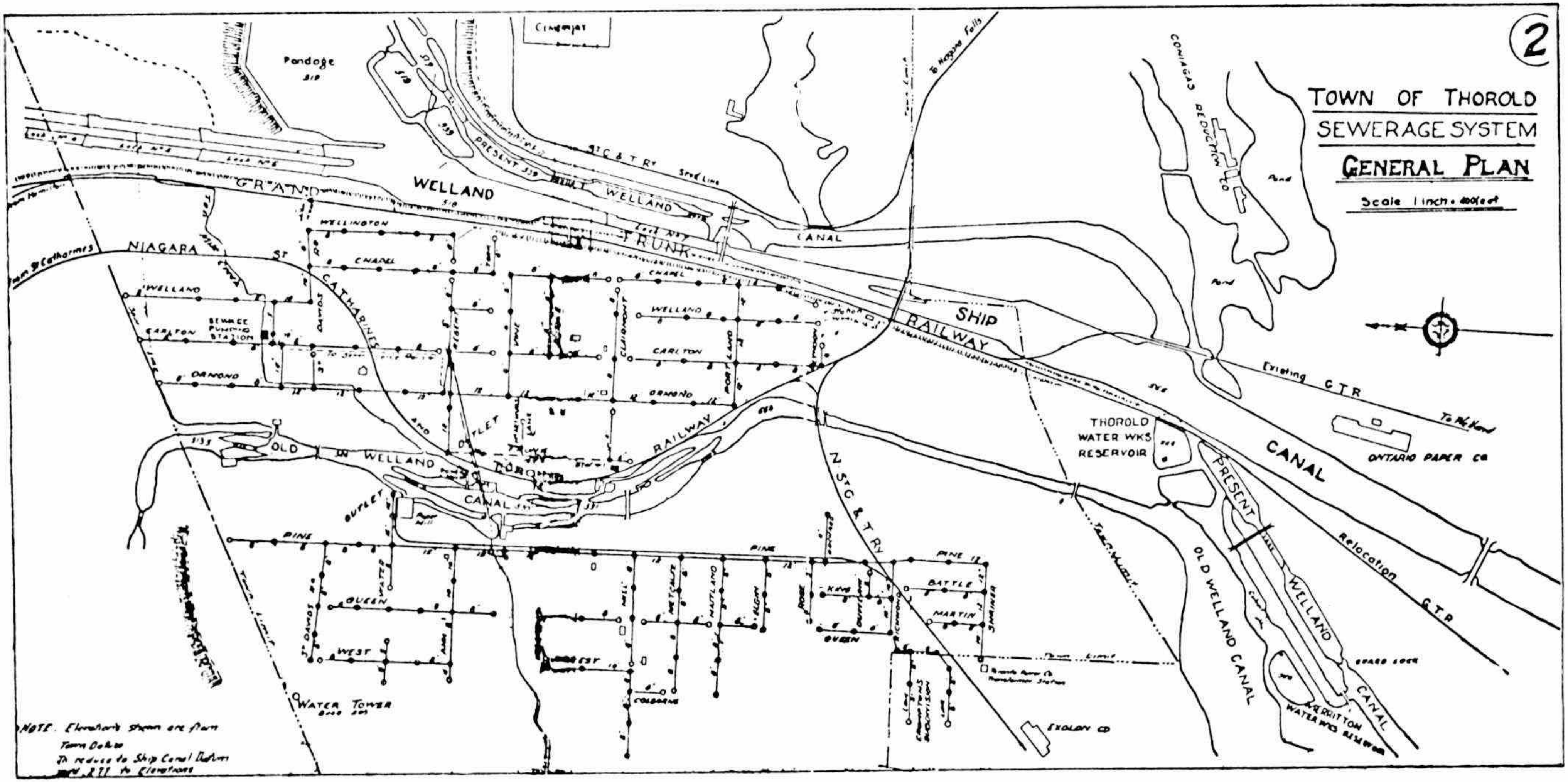


FIGURE F.15. THE CHIPMAN AND POWER SANITARY COLLECTION SYSTEM

During the years 1958 to 1967 the second Welland Canal was filled from the Thorold Expressway to Townline Road, but a major storm sewer known as the "Second Welland Canal Storm Sewer" was installed first. Adjacent to this storm trunk sewer the Thorold Sanitary Interceptor Sewer was constructed as an OWRC project. It intercepts eleven sanitary sewers outletting into the Second Welland Canal and limits the sanitary flows entering St. Catharines to 15 cfs, while daily flows are recorded at this boundary by means of a Parshall Flume. The sanitary flow then is conveyed via the City of St. Catharines-Port Weller Trunk Sewer to the Port Weller Sewage Treatment Plant.

The major paper mills in Thorold, such as Provincial Paper, Domtar and Ontario Paper, used the Second Welland Canal as a convenient outlet for their untreated plant wastes.

The Town's system and its problems are very complex indeed, with part of the present urban drainage areas located in the watershed of the Second Welland Canal, part in the watershed of Ten Mile Creek, Lake Gibson as a receiving water of storm overflow of the newest subdivisions, part of the sewer systems being truly combined, part being perverted sanitary systems, part being separate systems which are actually partially semi-combined and the major storm drain (Second Welland Canal Storm Sewer) serving mainly as an industrial waste sewer.

The conclusions and recommendations of the 1970 report provide a further insight into the more urgent sewer problems encountered in the original Town of Thorold urban area and may be quoted as follows:

"<u>Conclusions</u>

1) The "Chipman and Power" Sanitary Sewer Collection System was designed and is still adequate for today's sanitary sewage flows.
2) Flooding problems incurred since the installation of the "Chipman and Power" system are a result of the use of this system for storm drainage purposes.
3) Many of the storm sewer works constructed to relieve the flooding of the "Chipman and Power" system must be abandoned in favour of a complete, new, separate, storm sewer system.

4) The Ten Mile Creek outlet was under-designed and this fact may hinder further development in that drainage area.
5) Flows in the Thorold Sanitary Trunk at Townline Road now regularly exceed 15 cfs. Since Thorold's agreement with St. Catharines limits the flow to 15 cubic feet per second in this trunk, we feel that no new connections should be made to it until some system separation is achieved.
6) With the exception of the Westmount and Meadow Acres subdivisions, only the Garden Street and Pine Street links are required to complete the sanitary sewer system. The cost of these works to the Town (after subsidies) will be about $15,000.
7) Major storm sewer works must be undertaken in order to relieve the sanitary sewer system from storm waters. The cost of these works to the town (after subsidies) will be about $126,000.
8) A new sanitary sewer system is required in the Westmount and Meadow Acres subdivisions. The cost of these works to the town (after subsidies) will be about $255,000."

"Recommendations

Our recommendations are as follows:

1) That the existing Town by-law forbidding roof water connections to sanitary sewers be enforced.
2) That the Town start immediately on a sewer construction program in all areas except Westmount and Meadow Acres. This sewer construction program should be designed to separate the sanitary and storm flows.
3) That the St. David's Street separate manhole be constructed immediately.
4) That adjustments to the separator manholes be made now and from time to time as the systems are separated.
5) That, upon completion of the separation of the balance of the system, a new sanitary sewer system be installed in Westmount and Meadow Acres. We believe that no major road-

way improvements should be carried out in these areas until this system is installed.

7) That Plate 2 'Proposed Sanitary System' and Plate 3 'Proposed Storm System' be used to serve as a guide in the construction of the aforementioned works."

Since the submission of the above 1970 report, a continuous program of sewer separation and improvement has been carried out to primarily eliminate sewer surcharging and surface flooding. For instance, in the 1975-1976 budget about $250,000 (per year) was allocated and expended for the construction of new storm sewers to provide sewer separation. Some flooding occurred in 1975, but this occurrence was unusual as flooding of the 1975 magnitude has not been experienced before that year or since then.

There is no designated program for the replacement of old sewers. Most sewer planning concerns new development, with construction by subdividers, and pollution control. The latter, with respect to trunks, pumping stations and treatment, is now under the jurisdiction of the Regional Municipality. The city's primary concern now is, therefore, the upgrading of their existing local systems.

F.3.4 Town of Campbellford Sewer Systems and Problems

The Town of Campbellford's problems with their sewerage system are primarily financial at present. This may well be appreciated considering that not only is the town's current unemployment rate about 30 percent of the working population, but also that about 30 percent of its present overall municipal population is over the age of 60. The town not only serves as a retirement centre for the surrounding rural population but also its limited industry provides insufficient employment and income for the relatively small working segment of its population. Generally, with limited income and slow population growth, the means for sewer upgrading are limited. As well, the needs for such programs with respect to timing are not urgent.

In the past, the primary problem was pollution control. Because of increasing tourism in the area along the Trent River, cleaning up the river was most important to the town. The following quote from the 1973

official plan study for the Campbellford/Seymour area may illustrate this in more detail:

> "Until 1971, the Trent River, above Campbellford, had bottom fauna similar to the fauna found in unpolluted streams, but in Town, great numbers of sewage worms were found below the old treatment plant and cheese factory. Below the Breithaupt Leather Company, pollution of the water was also evident with high readings of phenol, giving the water an unpleasant taste, and organic nitrogen, causing algae blooms and dense mats of large algae and aquatic vegetation.
>
> In 1971, a new Ontario Water Resources Commission Sewage Treatment Plant was completed which has been able to provide a high degree of treatment despite high flows. The sewerage system still has certain problems resulting from its combined nature and some defective sewers, requiring repairs. As a result, the official plant capacity of 0.80 million gallons per day is being exceeded to the extent that 1.5 million gallons per day flow through the plant. This flow is much higher than the design stipulates, but the actual amount of organic matter is low so that the effluent is well within the Ontario Water Resources Commission requirements.
>
> The new plant has improved the water quality downstream, particularly at the point of discharge. After the plant was in operation, the water samples at the dam downstream from Campbellford showed a low biochemical oxygen demand (1-2 parts per million) with the dissolved oxygen above 7 parts per million and a coliform count well within the criteria for swimming.
>
> The Trent River is highly eutrophied throughout, so that there are general taste problems related to water quality along its course. However, this is not a unique problem in this area."

The high flow rate to the plant noted above is partially caused by extraneous flow entering the sewer system. As noted before, the canalization of the Trent River, with construction of a dam and canal section with sliplock, caused a substantial rise in the groundwater level in the town which, in turn, increased the infiltration in the older sewers. This appears to be one of the reasons why the dry weather flow is relatively high. Peak flows from the combined system are basically limited by Pumping Stations No. 1 and No. 2, because, although the unique "core wall sewers" along both sides of the river are the main collectors, they were not designed as interceptors. Overflowing simply occurs through holes in the core wall and at the storm outfalls at both pumping stations downstream of the river dam.

A 1971 report on inspection of the core wall sewers revealed that at that time an old water intake in the wall contributed 50 to 60 percent of the flow in the core wall sewer, while two old flushing ports built into the system were also leaking. But most of this flow spilled over the storm weir at Pumping Station No. 1 below the river dam. Thus, the core wall sewer acted as a river bypass around the river dam, but at the same time the Town's sewage flow to the treatment plant became considerably diluted.

The separate sewer systems are mostly found in the newer developments, with the sanitary sewers draining into the combined sewers and the storm sewers draining to creeks.

From 1972 to 1975 some $110,000 was expended on storm sewer construction, financed out of town funds and contributions by the county. A new $700,000 trunk sewer was scheduled to be constructed in 1977-1978, but to be mainly financed by others (federal, provincial and county funding).

As shown previously, on a relative per capita basis, Campbellford incurs the highest annual and capital expenditures for public works of the six case history municipalities investigated, while having the lowest assessment and per capita taxation. This essentially means that relative to the others, its public works costs take a much larger slice of overall municipal expenditures. Its relatively large financial support from outside is, therefore, well justified notwithstanding that its sewerage problems are relatively simple as compared to those of the larger municipalities.

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